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ABSTRACT

CONSERVATION OF A PROPERTY IS THE ABILITY TO RECOGNIZE THAT THE PROPERTY IN QUESTION HASN'T ALTERED, EVEN THOUGH OTHER PROPERTIES HAVE BEEN VARIED. IT IS PIAGET'S VIEW, CONFIRMED BY EMPIRICAL EVIDENCE THAT CHILDREN ARE NOT ABLE TO CONSERVE LENGTH UNTIL AGE 7 OR 8. RECENT CONCERN OVER CONFOUNDING VARIABLES LED TO THE PRESENT STUDY IN WHICH THE CHILDREN FROM THREE KINDERGARTEN CLASSES (N=71) WERE TESTED FOR CONSERVATION OF LENGTH AFTER DIFFERENT TRAINING CONDITIONS. ONE CLASS RECEIVED A PRETEST, TRAINING, AND POSTTEST; ONE CLASS RECEIVED ONLY TRAINING AND POSTTEST; AND ONE CLASS RECEIVED BOTH TESTS BUT NO TRAINING. THE TRAINING WAS THREE 20-MINUTE SESSIONS AIMED AT AN UNDERSTANDING OF THE PROPERTY OF LENGTH. ANALYSES OF VARIANCE DETERMINED DIFFERENTIAL EFFECTS ON PERFORMANCE OF THE PRETEST, THE TRAINING PROGRAM, AGE AND SEX OF THE SUBJECT, AND TESTER BIAS. RESULTS SHOWED THE TRAINING PROGRAM TO BE A SIGNIFICANT VARIABLE, AND GIRLS MADE GREATER GAINS THAN DID BOYS. (AUTHOR/MH)

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# AN INTRODUCTION OF LENGTH CONCEPTS TO KINDERGARTEN CHILDREN

Report from the Project on Analysis of Mathematics Instruction

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## STATEMENT OF FOCUS

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from Phase 2 of the Project on Prototypic Instructional Systems in Elementary Mathematics in Program 2. General objectives of the Program are to establish rationale and strategy for developing instructional systems, to identify sequences of concepts and cognitive skills, to develop assessment procedures for those concepts and skills, to identify or develop instructional materials associated with the concepts and cognitive skills, and to generate new knowledge about instructional procedures. Contributing to the Program objectives, the Mathematics Project, Phase 1, is developing and testing a televised course in arithmetic for Grades 1-6 which provides not only a complete program of instruction for the pupils but also inservice training for teachers. Phase 2 has a long-term goal of providing an individually guided instructional program in elementary mathematics. Preliminary activities include identifying instructional objectives, student activities, teacher activities materials, and assessment procedures for integration into a total mathematics curriculum. The third phase focuses on the development of a computer system for managing individually guided instruction in mathematics and on a later extension of the system's applicability.

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## Chapter I

## STATEMENT OF THE PROBLEM

At the Wisconsin Research and Development Center for Cognitive Learning an analysis of the elementary mathematics curriculum is being undertaken by a current project headed by Dr. Thomas Romberg (Romberg, Fletcher, and Scott, 1968). In the initial stages of this effort a task analysis was constructed in which the behaviors the children were to learn were clearly specified and related on a hierarchical basis. Much of the instruction subsequently developed centers around the notion of attributes or "properties" of concepts. Just as kindergartners can describe a stuffed animal in terms of its colors, size, shape, textures, etc., so they can also define mathematical principles in terms of their properties (i.e. what factors must we take into account when we discuss such notions as "number" or "length"?).

The attempt nowadays to tackle such learning problems as these invariably leads the enterprising researcher into the annals of Swiss psychologist Jean Piaget. His intensive questioning of young children has revealed many misconceptions with which they are saddled as they proceed along the path to adulthood and mature thinking. Although these errors take a rather wide variety of forms, many can be generally classed under what Piaget has chosen to call "conservation." Someone who can conserve understands that certain attributes of an object remain unchanged when certain other attributes are varied. For example, most adults would readily agree that ten red beads are still red whether we put them in a pile or spread them out in a row. They recognize the invariance of the property "color" under the transformation of the property "position in space." So do young children. But, alas, they fail to realize that there are just as many beads in a pile as in a row. Over and over again preschoolers will assert that the ten beads in a row are "more" than the ten beads in a pile. They do not yet see that the property "numerousness" does not change when we change the property "position in space." They do not conserve numerousness. Neither do they conserve mass (solid or liquid) or weight or volume or length or area or any number of other important attributes. Although a seemingly trivial mistake, it has generated much theorizing and much experimentation and has come to be a major phenomenon to be explained by anyone concerned with the growth of cognitive processes.

A growing body of Piagetian research has relatively recently entered the psychological limelight. Although much is concerned merely with replicating Piaget's work on a more systematic, "scientific" basis, the bulk of this literature could be said to center around the issue of "training." While Piaget postulates a stage approach to cognition and a changing mental structure (with the implication that a child cannot grasp a conservation task until his own structure has sufficiently matured) various investigators have asked whether it is not possible to teach the concepts underlying the conservation problem and so hasten correct performance. A variety of theoretical and methodological issues have arisen from this research.

A major source of controversy stems from the verbal nature of Piaget's interview technique. Many have argued that children simply do not fully understand such terms as "big," "more," "same." Children who are capable of conserving are thus judged to be non-conservers simply because they do not understand the questions put before them. The usual technique for circumventing this semantic difficulty has been to devise discrimination tasks, which are essentially nonverbal (Braine, 1959). Studies which do consider the verbal problem but retain the same basic format often drill the child first in the relevant terms and then assume thay are significantly understood so as not to be an interfering factor.

Surprisingly, even those studies which have been specifically directed toward the verbal influence in Piagetian research have not proceeded on a definitional basis— i.e. just what do we mean when we ask "how many?" or "how long?" What are the important elements that must be considered? A child who successfully selects the longer of two sticks on several occasions still does not necessarily understand the various factors included in the adult's concept of "length," factors that Piaget himself makes the basis of his interrogations.

Here, then, seemed to be an ideal meeting ground between the mathematics program already underway and some Piaget-based investigation. This exploratory study was undertaken to determine kindergarten children's ability to work with the notion of length. The children were introduced to this principle in terms of its "properties." That is, just as objects can be described in terms of color or shape or size, so they can also be discussed in terms of length. And the notion of length has several properties all of which must be considered when making a judgment. Would an explanation of these properties--i.e. Here are the things you must take into account when determining how "long" something is. This is what we mean by the word "length"--increase performance on Piagetian tasks involving conservation of length? Since it has been repeatedly argued that children do not have the same understanding of these mathematical terms as do adults, why not try to explain the more mature definition? This was, in essence, the purpose of this study. It was intended as a rather global approach to the problem and an indicator of possible directions for further effort.

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## Chapter II

## REVIEW OF THE LITERATURE

The influence of dimensional training on related tasks, and particularly on conservation behavior, must be considered along with an understanding of the overall body of conservation literature which has emerged in recent years. This literature reveals several major issues that have arisen regarding Piagetian research and provides a broader context in which to view the present study.

Since there are a variety of attributes to be conserved there are a variety of conservation-type experiments, each of course looking at somewhat different phenomena but clearly falling under the same general category. For instance, a child conserves mass when he recognizes that two equal clay balls are still equal (in amount of material) when one of them is rolled into a sausage. To a nonconserver, a standard amount of liquid becomes "more" or "less" than its equal when it is poured into a container of a different shape and hence reaches a different level. Conservation of length occurs when the child realizes that two sticks are equal not only when their end points are even but when they are staggered (Figure 1).



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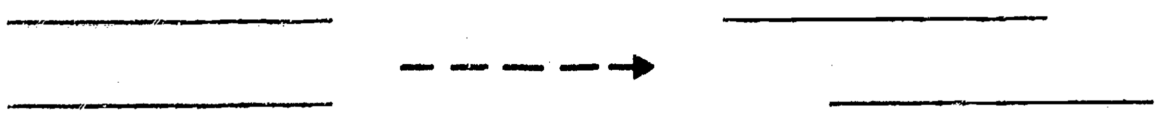
Figure 1

A Classic Conservation of Length Task



Generally, then, in a conservation question two objects are shown to be the same on property A. An alteration is made on one of these objects with respect to some unrelated property B. The non-conserver believes that A too is affected. Furthermore he will state, for example, that the lines are just as long, now this one is longer, now that one is longer, now they are the same again -- without any awareness of the incongruity of his answers.

Conservation plays a key role in Piaget's developmental, stage approach to cognition. He sees four basic levels of thought, the first of which is the sensorimotor period of babyhood. The pre-verbal infant gains practical knowledge and builds up important mental structures through his actions upon the environment. The youngest child can perform actions but cannot represent them in any symbolic way. Next comes the period of pre-operational thought, with the beginning of language and therefore of representation. But the cognitive actions of this level have yet to be organized into any real, integrated system. This is to be the basic achievement of the concrete operational period, when the child comes to form hypotheses from his manipulations with concrete objects. It is at this time that the acquisition of the various conservations takes place. Finally, at the highest level of formal operations, the individual can think not only about objects but also about his own hypotheses; as Flavell (1963) suggests, he can now think about his own thinking. Piaget has described elaborate structural elements of each of these periods, borrowing heavily from mathematics.

According to Piaget (Ripple and Rockcastle, 1964, p. 8), knowledge is action: "To know an object is to act on it." Thus the essence of knowledge is the operation, or a set of actions by which the individual modifies an object and thereby comes to understand it. An operation is not an isolated event but is part of the total mental structure at any given time. It is the development of this mental structure, becoming more and more an integrated system of cognitive experience, that proceeds along the path just described.

Now it remains to be asked just how this process occurs. What causes the growing child to pass through each of these levels of development? This is one of the key components of Piagetian theory and one of the areas which conservation experiments are designed to explore. Piaget lists four factors in this developmental sequence. Maturation is certainly one element--but not all-important: witness the age variations. Not all children reach the same level at the same age (The stages themselves are said to be invariant--all children go through them in the same order. But the specific age at which a given period is reached will vary among children, although generalizations can be made.). Experience, too, plays a role--both physical and mental. This is, of course, in accord with Piaget's emphasis on action. Nor does he rule out social transmission, linguistic or educational. But again, this is not a sufficient explanation since the individual, in order to properly receive the information, must have a structure which enables him to integrate it within his existing cognitive system. Finally, Piaget lists equilibration. This is the prime factor and a concept vital to his whole theoretical framework.

Knowing is an active process. In every cognitive act the individual adapts to the environment (accommodation) and at the same time integrates it into his own mental structure (assimilation). He continually responds to the environment but according to his own internal framework. When these inseparable processes of assimilation and accommodation are in balance, the individual is said to be in a state of equilibrium. And this is indeed the tendency, since when faced with external disturbance he will react in order to compensate. The succession of levels of equilibrium is the equilibration process, or the process of bringing assimilation and accommodation into balance. Thus, it is not external reinforcement per se which brings about learning, but rather the influence of the child's activities on each other and the child's active interaction with his environment. A stimulus is meaningful only to the extent that there is a structure which permits its assimilation, and it is the structure which sets off the response. Between the stimulus and the response is an active, cognizing organism.

Now to return to the matter of conservation. This is additionally explained by Piaget on the basis of centering. At first the young child is said to center, or focus, on only one aspect of a problem situation. He will concentrate on length or width in the ball of clay, for example, but not both. Moreover, after concentrating on one property he will then switch to the other. It is not until he begins to look at both properties together that the transition to conserving behavior occurs. This finally happens when the subject sees a meaningful pattern in the inter-relation of these properties under a transformation. Thus, he realizes that as the ball becomes a sausage, length increases but only at the expense of width.

Finally, Piaget discusses conservation in terms of several other main concepts, the chief of which is reversibility. This involves the notion that an object which is changed in some way can be returned to its original state by an inverse action. Thus, the sausage that was once a ball could be made into a ball once again. The logical multiplication of relationships is another important operation; it occurs when the subject centers on both relevant properties and compares them simultaneously--the column of liquid, for example, being both narrower and higher than a standard. Both of these in some way involve the principle of identity; it is still the same clay or liquid or line no matter what shape or position it assumes.

It might be pointed out that Piaget has built up his discussion and theory not from traditional psychological experimentation in the American sense but from extensive interviews with children. His writing consists basically of reports of these question-and-answer sessions interspersed with generous interpretative commentary. His data are accepted with little question--after all, they are obtained verbatim from the subjects themselves. His interpretations, on the other hand, are quite open to debate and have led to the many attempts at clarification. Significantly, Piaget's findings have been confirmed in that there does seem to be a rather set series of stages through which children pass before conservation is attained. Rather, it is the dynamic processes underlying this developmental phenomenon that has captured the attention of growing numbers of psychologists and educators alike.

Much of the controversy at first seems to be a rather trival question of age norms: just when does the average child achieve the various conservations? One quickly realizes, however, that this surface argument actually involves important issues delving into the forces underlying conservation. Thus, perhaps it is true that in the normal course of events children begin to acquire conservation-related concepts naturally at around the age of seven, as discovered by Piaget. But is this only because they have not been exposed earlier to relevant mathematical principles, even at a most introductory and elementary level? Is it simply that they <u>do</u> not conserve earlier, because no one seems to require it just yet and no particular effort has been made to teach it in the usual sense; or is it truly that they <u>can</u> not conserve for lack of a sufficiently developed cognitive apparatus? It is the research to be reported which essentially has come to grips with problems such as this, and has in the process raised the important issues which have come to surround the topic.

One focal point of study has been an attempt to test Piaget's equilibration theory against a more traditional S-R approach. Using extinction to test the relative merits of equilibration vs. learning theory, Smedslund (1961, III) devised what has come to be one of the most often cited studies in this area. Learning theory would predict that any response is subject to extinction under non-reinforcement, whereas equilibration theory postulates a firmly held cognitive belief that, once acquired, will continue to hold up even against what seem to be counter instances. When Smedslund deviously removed some clay from his balls, he found that subjects who had acquired the conservation concept during the course of the experiment showed no resistance and accepted the results without any great surprise. Half of the "natural" conservers, however, insisted that the experimenter must have made some unknown manipulation. Conclusion: in favor of equilibration!

In a related study, Smedslund (1961, V) took a somewhat different approach. The equilibration explanation sees conservation (as other concepts) acquired by a process of internal reorganization, independent of external reinforcement. Traditional learning theory would of course assign prior reinforcement of conserving responses as the important variable. Smedslund tried to induce this reorganization by causing a cognitive conflict; he rolled a ball into a sausage but at the same time added or removed a small piece. This procedure with no reinforcement resulted in a few subjects achieving conservation, leading him to believe that this training method might be a particularly effective one.

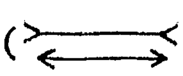
Kingsley and Hall (1967) report a training procedure which they found very successful in bringing about conservation behavior, this one quite clearly on the learning side. They used an "approach which analyzes the material to be taught into a hierarchy of subtasks [p. 1112]," hypothesizing that most training attempts have ignored the large amount of background information necessary for conservation and therefore the amount of time needed for training.

Watson (1968) gives an interesting analysis of conservation in S-R terminology. He points out that the basic response criterion is the subject's answer "the same" when asked about a transformed object. He notes that the "natural" conservers in Smedslund's experiment may well have had a prior history of reinforcement for conserving responses and therefore would have been expected to be more resistant to extinction. In a conservation experiment it is of course the transformation which is the stumbling block; there would be no problem without it and it is usually regarded as a perceptual factor which must be overcome by a conceptual one. The object in question may look bigger but we know it is really the same. Yet Watson presents the idea that from an S-R point of view conservation behavior occurs not in spite of but because of this transformation, for it is the transformation which is the discriminative stimulus. Watson's suggestion for a test of the two theories involves pretraining subjects on variations of a conservation task such that in the key situation the prior reinforcement would lead to a non-conserving response. Thus, in this situation correct answers would favor an equilibration interpretation.

Another growing body of conservation literature has looked not at the grand process of equilibration but at more specific operations discussed by Piaget. Thus Piaget says that a conserver must understand the property of reversibility; he realizes that the sausage could be returned to its ball state. So what would happen if we base a training program on the notion of reversibility? Or addition/subtraction (mass does not change unless we actually add or remove a piece)? Or multiple relations (e.g. length increases as width decreases)? Would conservation ensue?

The results of such studies are quite ambiguous, since the outcomes are not always consistent but of course somewhat different methods and experimental designs have been used. Generally it would appear that training in such properties as these has not been particularly successful. Wohlwill and Lowe (1962) used several different procedures and found no significant differences among them. Furthermore, none of them led to an understanding of conservation as demanded by the posttest. Regardless of isolated instances, there is little doubt that it is at any rate a difficult matter to teach conservation by any technique. And there is no indication that success on one conservation task will transfer to another.

As mentioned earlier, it is probably the verbal element of Piagetian research which has generated the most discussion. Probably the leading spokesman for the necessity of introducing a non-verbal assessment technique is Martin Braine (1959). In "The Ontogeny of Certain Logical Operations" he emphasizes the point that non-verbal techniques must be used to test a theory which postulates a change in thought (as opposed to language) processes.

In order to obtain less equivocal results Braine designed a length discrimination task in which selection of the longer (or shorter) stick was rewarded with candy. He introduced illusory effects such as Mueller-Lyer arms () in order to further ensure that the correct solution was obtained through proper measurement and not just perception. In

Braine's situation, subjects watched the experimenter successively compare each of two sticks (A and C) with one intermediate (B) in size. They were to find the candy by making the transitive conclusion that if A>B and B>C, A>C. Under these conditions 50% of the children were able to make this deduction between the ages of 4-2 and 5-5, considerably earlier than Piaget had indicated. Although this was not strictly a conservation task, presumably it could not have been solved by non-conservers.

Although Braine's original experiment was designed largely to combat the problem of verbal influences, his monograph became the basis of a lengthy debate between himself and Smedslund, who criticized various points of Braine's methodology (See Smedslund, 1963, 1965, 1966 and Braine, 1959, 1964). Although the initial questions were sometimes lost in the shuffle, their exchange provides a most instructive example of the problems inherent in developing a "crucial" psychological experiment and in interpreting any results.

Smedslund's most serious criticism centered around the fact that Braine's subjects could possibly have answered correctly (found the candy) on the basis of what he called "non-transitive hypotheses." That is, they could have depended on aspects of the measuring procedure, or on either A>B or B>C without combining the <u>two</u> facts into the conclusion A>C. Smedslund devised his own experiment to test for emergent measurement behavior in children and concluded (as did Piaget) that the behavior in question appears at around age eight.

Braine countered that these subjects probably could not distinguish whether the experimenter was asking about which _is_ longer or which _looks_ longer (verbal problem again).

More recently, Smedslund found that subjects performed significantly above chance on pseudo-measurement tasks; the only way to do this was to choose one stick longer than another stick with no concern for the validity of the total measuring procedure. He concluded that Braine's non-verbal reinforcement method is not a valid instrument for diagnosing transitivity of length, and that his 5-year-olds probably did not have a grasp of the concept.

Thus, at the heart of this debate are some important, unsolved issues. Just what _is_ conservation? Is verbal conservation the same as non-verbal conservation? Do different assessment techniques actually measure the same behavior? Are Piaget's results more than somewhat arbitrary decisions based on his own unique investigatory procedure?

Inhelder (1966) comments that some of the differences have been found because a child's cognitive system cannot be evaluated by a "rather summary investigation of answers to pre-selected questions with no exploration of the child's justification of these answers [p. 162]." In other words, the presence of conservation _must_ be determined by a probe in depth of the child's thinking, which _must_ involve a language-based procedure such as Piaget's. Yet this still does not answer the relevant point that terminology _can_ be a factor militating against conservation responses if children and adults have a different notion of what constitutes "bigness," for example. Indeed, Gruen (1966) suggests that the discrepancy in age norms found by Braine and Smedslund has resulted from their using different sets of criteria to assess the presence of conservation. Whereas Braine considers a subject a conserver merely if he gives a conserving response, Smedslund requires a subject to give a logical explanation. Here again the differing role of language is the critical factor.

And there is some evidence to indicate that the terms relevant to conservation research are in fact not clearly understood by young children. In a study exploring children's understanding of relational terms, Griffiths (1967) found that the word "same" is used correctly significantly less often than are "more" and "less." "Same" is of course the key answer in a typical conservation item. The experimenter suggests several reasons for this finding. First, there is the question raised by Braine: Does "same" mean <u>look</u> alike or <u>really</u> alike? Also, how similar must two objects be before subjects will assert that they are indeed identical? Finally, there is perhaps a greater tendency to note differences than similarities. In another study (Gruen, 1965) verbal pretraining alone was about as effective as either direct training or cognitive conflict in the inducement of number conservation. Conclusion: ". . . an experimenter who uses a verbal test of conservation must be certain that subjects understand the language he is using. Otherwise a child capable of conserving may be deemed a 'nonconserver' erroneously [p. 977]."

In a matter related to that of language, Braine and Shanks (1964, 1965) have raised the issue of phenomenal versus actual size. A conservation problem can be seen as one in which a purely perceptual judgment would dictate the wrong answer. The child must rely not on appearances but on an internal concept of what must be reality. Thus, Braine hypothesized that younger subjects spontaneously interpreted the question "which is bigger?" to mean "which is phenomenally (perceptually) bigger?" In two related experiments he found that by the age of five, children could distinguish between real and phenomenal attributes. They could answer differentially the questions "Which looks bigger?" and "Which is really, really bigger?" He went on to speculate that what must be explained in accounting for the conservations is the emergence of a broad conceptual distinction between real and phenomenal attributes.

Zimiles (1963) also presents an interesting viewpoint with an emphasis on the perceptual nature of the conservation task. He notes that the young child's concept of quantity (before language facility, before counting) is at first based exclusively on perceptual cues of length, height, weight, etc. A line is "long" when its ends are far apart, regardless of whether the path of that line is straight or quite round-about. Something is "heavy" when it is massive. There are "many" of an object when they take up a lot of space. In fact, such perceptual dimensions actually constitute the definition of quantity for the preschooler. It is only with the advent of mathematical skills such as counting that the child can make increasingly quantitative (rather than qualitative) judgments. Zimiles thus discusses the three stages leading to conservation in these terms:

I. No conservation. Subjects respond to the word "more" (in the case of number) "in terms of whatever dimension is suggested by the experimenter . . . . They will interpret the experimenter's manipulation of specific perceptual dimensions as an indication of the particular concept of quantity required by the task [p. 693]." This is in accord with various reports that children often consider the particular set that happens to be manipulated as the one that is "more."

II. Transition. These subjects show the beginnings of quantitative responses, but they simply have not had enough experience with these new mathematical principles to reduce the role of perceptual factors.

III. Conservation. Occurs when there has been sufficient opportunity to master quantitative skills and to compare them with perceptual factors, thereby recognizing the increased precision achieved with the former techniques. This process is of course something of a cognitive reorganization and is in this sense not completely at odds with a purely Piagetian interpretation. Yet more than Piaget, Zimiles seems to emphasize specific, experiential factors in the gradual change from perceptual to conceptual dominance.

In a final branch of conservation literature to be discussed, the roles of perception and language are examined under somewhat different perspectives by Bruner and his team of researchers at Harvard (1966). Basically, Bruner looks at conservation with the idea that language is the mediator enabling the subject to overcome "perceptual seduction." He views the lack of conservation as a misleading perceptual representation rather than as merely the absence of appropriate logical structures. It is the development of language which allows the child to represent the problem in nonperceptual ways and hence to recognize the discrepancies between appearance and reality. Language is critical; it is the vehicle of representation, the implement of knowing, the release from immediacy (1964). "If a child is to succeed in the conservation task, he must have some internalized verbal formula that shields him from the overpowering apperarance of the visual displays [1964, p. 7]." Bruner also agrees with Braine that words like "same" and "more" do not have the same senses to children as to adults, and that a less verbal, more action-oriented method of investigation is needed.

This, then is the matter of conservation and any new experiment must be regarded against this overall background. Perhaps more immediately relevant to the present study is a small body of work specifically in the area of conservation of length. Of primary interest here is the work done by Braine and by Smedslund, already discussed.

Coxford (1963, p. 423) has provided a convenient summary of Piaget's measurement research (Table 1). The letters refer to each of the various tasks, taken from The Child's Conception of Geometry (Piaget, Inhelder, and Szeminska, 1960):

A: spontaneous measurement--building a tower
B: judgment of distance--for example, with screen interposed
C: judgment of length--coincidence of extremities
D: judgment of length--sticks staggered
E: provoked measurement--children shown how to measure sticks
F: use of perpendicular measurements to locate a point
G: subdivision of a line

Lovell, Healey, and Rowland (1962) carried out several Piagetian measurement tasks with children in England, from both regular and "educationally subnormal" schools. They computed a correlation coefficient between chronological age and stage, and their results broadly confirmed Piaget's proposals. That is, they did find support for a stage classification of behavior, although the numbers in each category were not always what Piaget would lead one to expect.

Questioning whether training can improve performance beyond what an age-stage hypothesis would predict, Beilin and Franklin (1962) tackled this problem for length and area measurement with first and third graders. Ss were first asked to judge comparative lengths, with measuring devices available, and then divided into two groups for each grade--one receiving instruction and one not. General results tended to support Piaget in that first and third graders did perform differently, length measurement being accomplished before area measurement. Interestingly enough, however, both instructed and non-instructed first graders showed gains in length measurement, indicating that the Piagetian

Table 1

Measurement Concepts and Approximate Age Range of Attainment
(Coxford, 1963)

| Age | | Measurement Concept |
|---|---|---|
| Up to 4-1/2 or 5 | A. | Visual transfer of lengths (they look the same) |
| | B. | No conservation of distance (measure of empty space) |
| | C. | Length (measure of occupied space) determined by end points |
| | D. | No conservation of length |
| | E. | Inability to measure, i.e., no use of iterated units |
| | F. | Visual estimate to locate a point in 2 or 3 dimensions |
| | G. | Inability to subdivide 2 line segments equally |
| 4-1/2 or 5 to 6 | A. | Visual transfer augmented by manual transfer (bringing objects closer together) |
| 6 to 7 | A. | Body transfer of lengths (a third term introduced) |
| | B. | Occasional conservation of distance |
| | #C. | Length no longer determined by end points, but by configuration of material between the end points* |
| | D. | Gradual awareness of conservation of length |
| | E. | Trial and error measurement and inconsistent use of units |
| | F. | Use of rulers to aid visual estimates |
| | G. | Trial and error subdivision of line segments |
| 7 to 8 | A. | Transfer by means of an object (independent of the body) longer or the same length as the object to be measured. Transitivity of length--mean age 7-1/2 |
| | #B. | Conservation of distance. Symmetry (AB = BA) |
| | #D. | Conservation of length--one-half of those 7 to 7-1/2 and three-quarters of those 7-1/2 to 8-1/2 |
| | F. | Realization of need for 2 or 3 measurements in locating points, yet no coordination of length, width, and height |
| | G. | Accurate subdivision of line segments |

Table 1 cont.

Measurement Concepts and Approximate Age Range of Attainment (Coxford, 1963)

| Age | | Measurement Concept |
|---|---|---|
| 8 to 9 | #A. | Operational measurement, i.e., use of rulers shorter than the object and unit iteration |
| | #E. | Unit iteration and accurate measurement--mean age 8 to 8-1/2 |
| | #G. | Use measurement to check on accurate subdivision of line segments |
| 9 to 10 | #F. | Use of 2 or 3 perpendicular measurements to locate a point--mean age 9 to 9-1/2 |

*The symbol # means the final attainment of a concept was reached by the children. When a letter is omitted in an age range, the development is at the same stage as in the previous age range.

"test" itself facilitates learning. The authors concluded that training may yield gains in the right direction even if perfect operational measuring ability is not reached and that older, brighter children may benefit more from instruction.

Murray (1965) had school children judge the comparative lengths of perceptually confusing lines when the illusion-producing devices were added after the lines were seen to be equal. He was operating under the hypothesis that children may confuse "length" with "position of endpoints" and his study was designed to eliminate this confusion while assessing length conservation. His first graders differed significantly from second and third graders. Conservation appears to occur between the ages of seven and eight and evidently is a phenomenon referring to more than merely the position of endpoints. This experiment, though, does not as its author claims really present a non-verbal methodology.

Sawada and Nelson (1962) recognized the importance of the age question for curriculum and instruction. Looking at Braine's data, they proposed that first-grade teachers must couch instruction in as concrete terms as possible "so as to minimize the cruciality of verbal symbols which could turn our conserver (conserver as indicated by a non-verbal test) into a non-conserver [p. 346]." In a test involving the fit of calipers to rods, they concluded that the crucial age for length conservation is between five and six years, thereby supporting Braine.

A wide variety of techniques have thus been assembled as means of both training and assessing conservation. Nor surprisingly, different techniques and different emphases have yielded somewhat diverse findings. And the argument has persisted that the children did not understand the questions put to them anyway.

The definitional approach taken here is conspicuously absent in the literature. Yet Braine's statement (quoted in the "general discussion" section) would clearly point to such a procedure. Let us <u>tell</u> children what we mean by length, and <u>then</u> test them on related tasks.

Let us emphasize that an object can be described along many dimensions, one of which is length; and that "length" has certain properties inherent in the term which must be understood if one is to reach a meaningful conclusion. Focusing on relevant dimensions of objects and dwelling on their mathematical properties is an approach not yet taken in the area of conservation, and one barely beginning to appear on the broader scene of mathematics instruction in general.

## Chapter III

## THE EXPERIMENT: PROCEDURE AND RESULTS

The experiment was conducted in the fall of 1968 in the Mt. Horeb Elementary School. Mt. Horeb is a small, rural community near the university town of Madison, Wisconsin. Subjects included all members of the three morning kindergartens; all were white. Five children had to be eliminated because of absence on testing days or because of a complete inability (or unwillingness) to communicate with the experimenter. A total of 71 subjects (42 boys and 29 girls) was thus obtained, 70 of them ranging in age from 5-2 to 6-3. One child was a year older (7-3) but she was kept in the study on the basis of a performance not markedly different from that of other classmates.

The three classes were maintained intact as the three experimental groups. They were not originally selected on any systematic basis and there was no reason to assume that any relevant differences existed. Group I (N = 24) received a pretest, training, and posttest, while a control Group II (N = 23) was given only the pre- and posttest. To determine any instructional benefits gained from the pretest itself, Group III (N = 24) received the training sessions and a posttest. All work was completed within three weeks.

The pre- and posttests were identical, consisting of twelve short items administered to the children individually. Score was the number right (possible range was therefore 0-12). Six different experimenters carried out the testing. Children were assigned randomly with an attempt to equalize the sexes for each experimenter. The children were always pre- and posttested by the same individual. The tasks were designed to reflect the material covered in the training and to follow closely Piaget's own questions. They are discussed in detail later.

The training program was conducted by the writer on three successive mornings of the second week of the experiment. Each lesson lasted about twenty minutes and was directed to the class as a whole. This instruction was <u>not</u> specifically designed as a means of teaching conservation per se. In fact, the opposite approach was taken--that is, children were taught various concepts related to the notion of "length," the idea being that comprehension of what is inherent in the term would lead to better performance in tasks requiring several kinds of manipulations.

The first lesson was devoted to a discussion of "properties" of length. These were taken basically from Piaget's questions described in <u>The Child's Conception of Geometry</u>. Three main ideas were stressed: in making a judgment concerning the length of an object, we must, first, look at <u>two</u> ends; second, we must look at everything between those two ends (in other words, the path of the object); and finally, the length of an object does not change when we move it.

First, however, it was necessary to direct the children's attention to the idea of length in the first place, to the idea of length as one way to describe objects. This was accomplished by E holding up two crayons differing along several dimensions -- a green one, long, covered with paper, and pointed; a red one, short, no paper, blunt -- and asking, "How are these different?" It was seen that we can describe objects in several different ways, one of which is length, or how <u>long</u> things are. With the crayons it was easy to determine their length, but sometimes it is not so easy and then we have to know just what it is we mean when we talk about this property.

Principles of length were illustrated first with string. To see how long a piece of string was, we had to look at <u>both</u> ends, (i.e. from <u>here</u> to <u>here</u>) and then all the string in between those ends. Children drew along the string and saw that the same piece could produce all sorts of configurations, all of which were the same length. Thus, if we looked just at the two ends (Figure 2) we would conclude that $A^1B^1$ was longer, whereas if we also looked at all the string in between we saw that maybe they were just the same. And if we passed the string around the room or threw it in different places on the floor, its length did not change with its location.

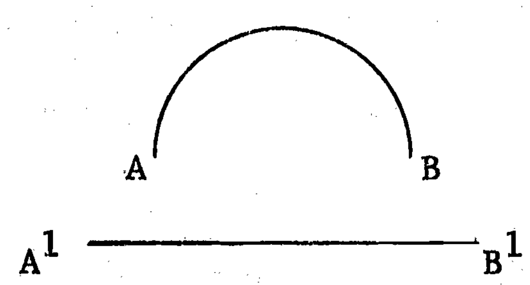



Figure 2

A Means of Illustrating Length Properties during Training

Height (or length from head to toe) was introduced as a second illustration. The children agreed that their height did not change as they assumed different positions: standing on the floor or on a chair, bending over, lying curled up or straight, walking. The head might be closer to the toe one time than another, but there was unquestionably the same amount of child in between those endpoints!

Finally, as a review of the three principles each child received a stick of licorice. His piece was just as long if he kept it straight or bent it or tied it in a knot or put it in his pocket.

The second training session was concerned with comparing lengths. Here the children were taught to put one end of each object together, and then have them follow the same path. Similar materials were used as illustrative devices: strings, colored paper strips folded in various ways, and again the children's own height. In this latter case lengths were compared by seeing which of two children was taller. A shorter person standing on a chair might look taller, but that was only because the endpoints were not placed together -- i.e. one set of feet was on the floor and one on the chair, not a fair basis for comparison! And if one child lay down so that his body was straight, and a taller one lay down next to him all curled up, we could not say that this second child suddenly became shorter. He simply looked shorter because their bodies were not following the same directions.

Representing length was the subject of the third lesson. Why bother to represent length? Sometimes the comparison procedure discussed in session two simply will not work, namely, when we cannot put those ends together. What about the case of lines drawn on paper, or colored strips glued together in a star (Figure 3)? In such situations we can use string or paper or something with which we can compare directly. The necessity of representation was made particularly apparent by the use of two colored paper strips glued down to form the "T" illusion (Figure 3). Without exception the children thought the vertical line to be longer, but when they used string to "measure" they were noticeably surprised to find both lines equal. When do we need to represent length in practical situations? Suppose we wanted to move various objects outside of the room. Which would fit through the door -- the piano? table? bulletin board? Again, these questions could be easily answered with a bit of string. At the end of this last period, the three days' material was quickly reviewed.

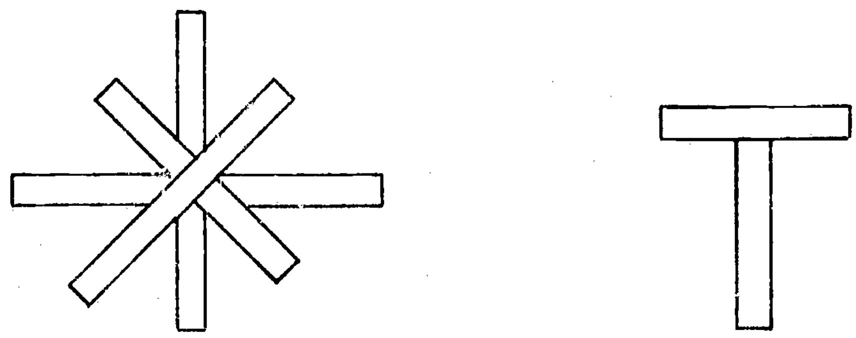


Figure 3

Two Methods Used to Illustrate Representation of Length during Training.

The major hypothesis concerned the effects of the training program, that children exposed to this brief instruction would show performance gains. The third experimental group was introduced to explore the possibility that the pretest itself is a learning experience, as suggested by Beilin and Franklin (1962). The data were also analyzed to reveal any sex or age differences in performance. Because several experimenters participated in the testing, it was necessary to consider any possible bias from this source. Four ANOVAs were run to determine the differential effects of these various factors.*

General trends can be seen most quickly from a look at the mean scores (Table 2):

Table 2

+Group Means on the Pre- and Posttests

| | PRE | POST |
|---|---|---|
| Group I | 3.38 | 5.63 |
| Group II | 3.00 | 3.70 |
| Group III | -- | 5.00 |

+Possible scores range from 0 to 12.

The training groups (I and III) seem to have gained somewhat from instruction, with the pretested group doing slightly better. The pretest scores leave little doubt that these subjects lacked an understanding of the relevant concepts. And certainly the posttest means do not indicate a startling shift in the direction of sudden comprehension. Yet whereas only one child achieved a score higher than 6 on the pretest (this being a score of 7, in group II), and only one child in Group II reached a score of 7 on the posttest, seven children in each

*All ANOVA tables (Tables 3, 4, 5, 6) are included together at the end of this section. Analyses were performed by the technical staff of the Wisconsin Research and Development Center, using the Finn (1967) program for multivariate analysis of variance.

of the instructed groups correctly answered more than six items (several of these scores being as high as 10 and 11). Figure 4 indicates the distribution of scores by group on both tests.

To test the main hypothesis -- concerning training effects -- a three-factor (training, age, and sex) analysis of variance with repeated measures was carried out on the pre- and posttest scores of Groups I and II (Table 3). Results indicated a significantly greater gain made by the group (I) which received instruction ($p < .02$).

Hoyt reliability figures further attest to a training effect (Table 7):*

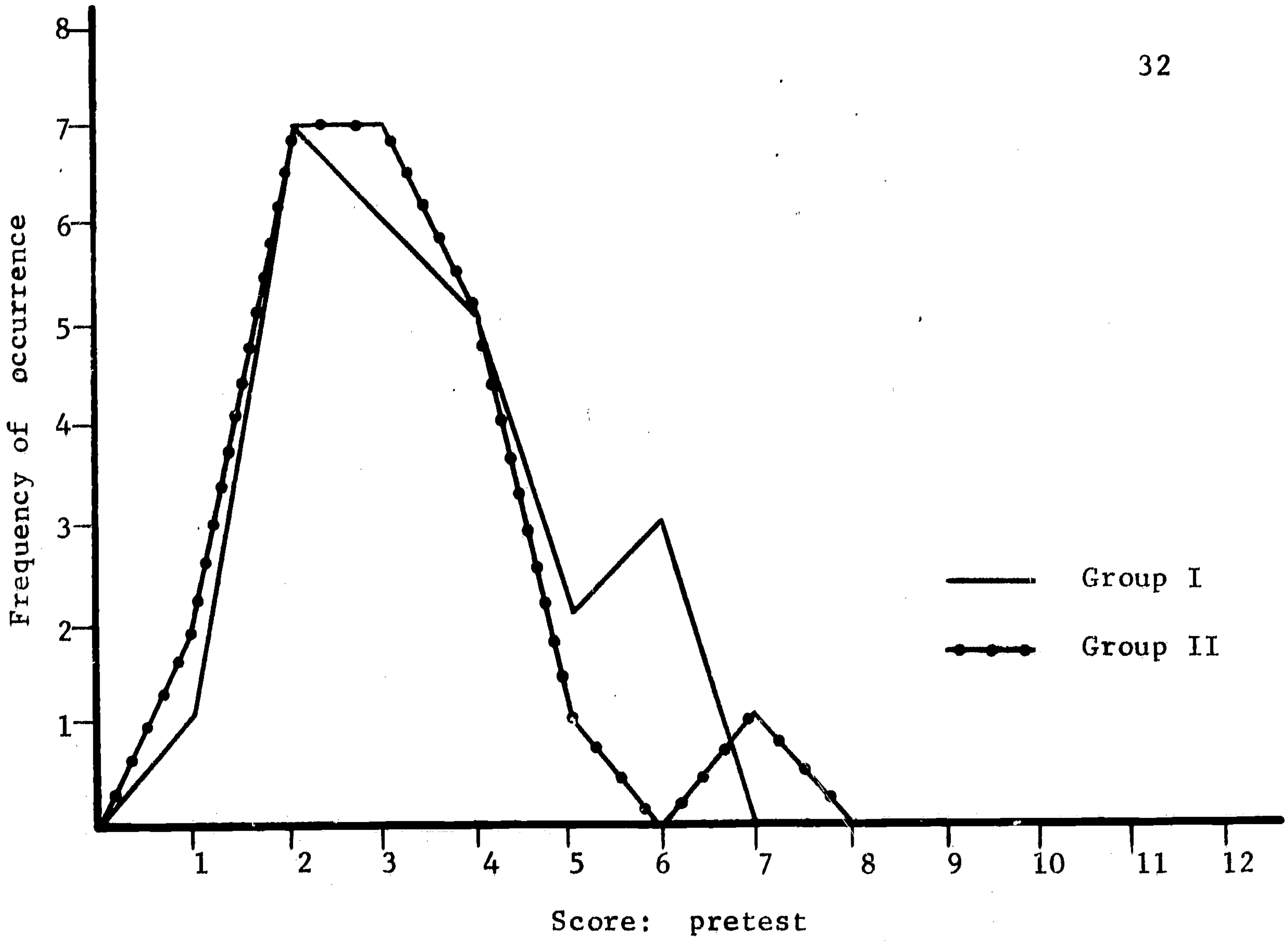
Table 7

Group Reliability Coefficients for the Pre- and Posttests

| | PRE | POST |
|---|---|---|
| Group I | .24 | .66 |
| Group II | .10 | .36 |
| Group III | - | .82 |
| TOTAL | .19 | .72 |

The low coefficients on the pretest suggest a rather haphazard pattern of response. Noticeably, the reliability measure for the uninstructed group (II) remains low on the posttest, whereas the higher figures for the

*Reliability coefficients were obtained by the technical staff of the Wisconsin Research and Development Center, using the FORTAP Program developed by Baker and Martin (1968).



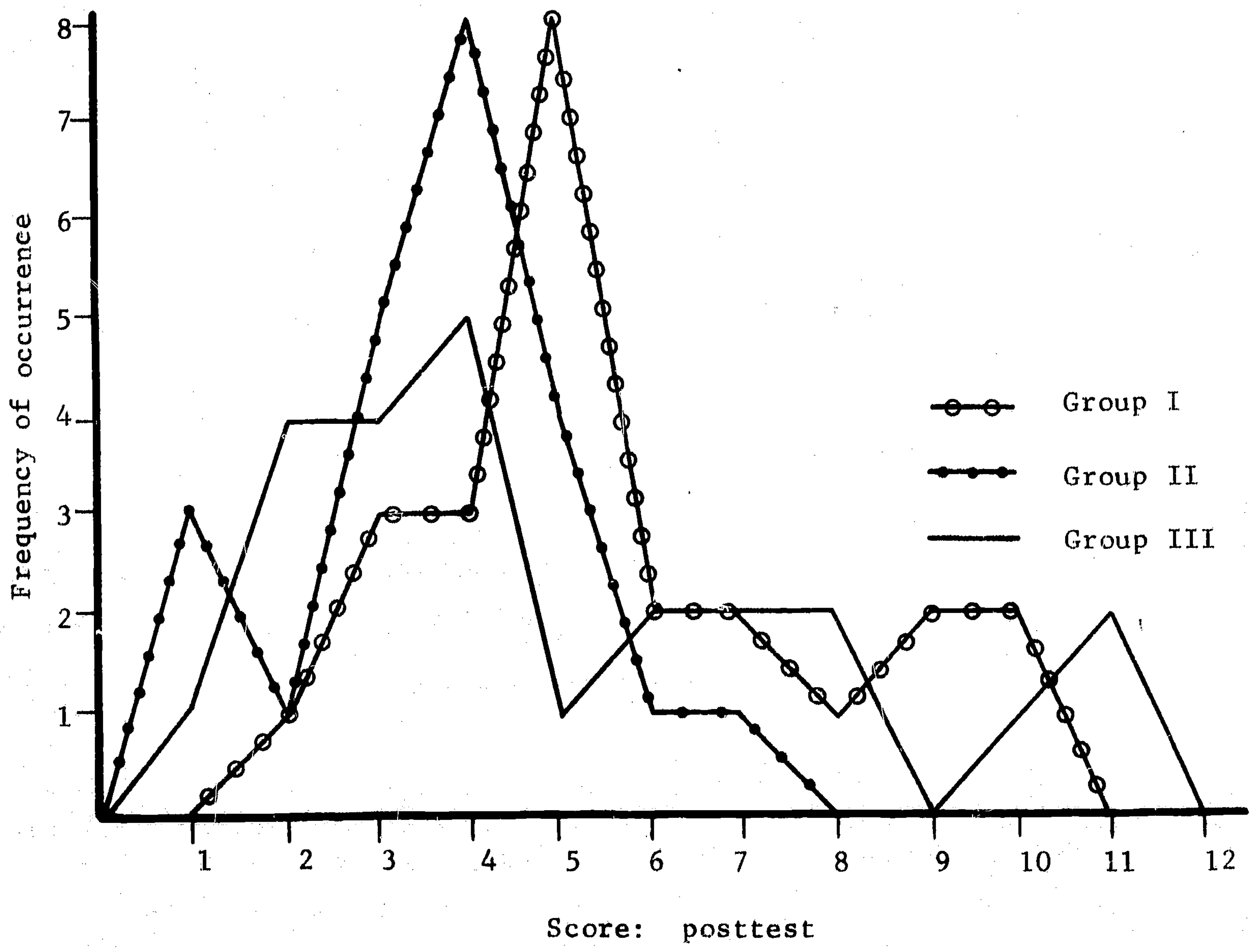




Figure 4

Distribution of Scores by Group on the Pre- and Posttests

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two training groups indicate a more consistent and therefore more meaningful approach by these subjects.

The analysis of variance (Table 3) showed that age (subjects were split at the median of 5-8) was apparently not a relevant factor, although one might have suspected that older children would have been somewhat superior on these tasks (age is <u>the</u> major variable according to Piaget). Neither was the age-training interaction a significant variable, indicating that older children did not benefit more from the instruction. Sex, however, did play a role. Girls showed higher gains on total score from pre- to posttest than did boys ($p<.04$). This may relate to general findings of girls' greater academic orientation in the elementary school years.

A second analysis of variance (Table 4) compared the posttest scores of Groups I and III, the three factors under consideration being pretest, age, and sex. Here there were three age levels: 5-2 through 5-5; 5-6 through 5-11; 6-0 and above. None of these variables alone accounted for a significant share of the variance, although the interaction of all three approached the .05 level. In this study, then, the very presentation of the pretest was not in itself a learning experience. It might be noted, however, that it did undoubtedly create a "mental set" toward length. In the first training session, it will be remembered, the children were asked to describe two crayons. Those who had not been pretested noticed the difference in color first and found it very difficult to name any other bases of comparison. On the other hand, children who had faced length-related problems on a pretest cited this variable first and then moved on to the probably more salient characteristic of color.

Finally, it was necessary to account for any variance in test score due to an experimenter effect. In a 2-factor (sex of experimenter and sex of subject) analysis of variance (Table 5) with repeated measures, using Groups I and II, the only significance lay in a greater gain made by the girls, a result seen earlier. Another ANOVA (Table 6) was conducted on all groups. This time sex of experimenter was the only factor. Results suggest a difference on particular items which was eliminated when the overall score is considered.

Generally, then, the major hypothesis concerning the positive influence of training was confirmed. The pretest, however, was not a significant variable in this experiment. Girls made greater gains on the posttest than did boys, while the performance of younger and older subjects was statistically the same. There was apparently no confounding bias due to the presence of several testers.

Since these results cannot be viewed meaningfully without knowledge of the individual items, it is now necessary to introduce a description of the tasks on which the data are based. Furthermore, the items were intended to tap several skills related to length, with the largest but certainly not the only emphasis placed on conservation. A closer item analysis will therefore reveal any patterns that might have existed as related to particular behaviors. All questions were scored either right or wrong. Some instances required a judgment by the experimenter as to whether the subject was indeed answering correctly, particularly on those items requiring manipulative responses. The order of items was always the same, there being no specific rationale for this order except in the case of #1.

Item 1

Materials: Two wooden stick-like blocks, one about an inch longer (Figure 5).

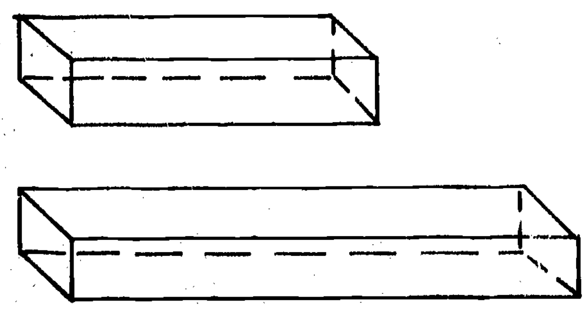

Figure 5

Materials for Item 1

Question: Are these two blocks different in any way, or are they just exactly the same?

Results: See Table 8

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Table 8

Results of Item 1

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 75 | 70 | - | 72 | 96 | 96 | 96 | 96 |
| R Bis* | .39 | .65 | - | .52 | .12 | .84 | .64 | .47 |

As the first item on the test, it was intended to determine whether the child even directed his attention to this factor of length. Subjects' immediate reaction was often to assert the blocks' equality, then after a moment's reflection to state that, no, one was "bigger." This was clearly the easiest of the twelve questions and would be expected to become even more so after either training or a pretest, both focusing on length concepts. Of the 47 children who took the pretest, 13 failed to recognize the length discrepancy. A common wrong answer involved a preoccupation with minor physical characteristics--"This one has a little crack right here;" "This one has a line on it and that doesn't"--with an affirmation that these were indeed the only differences. Only one child in each of the three classes missed this question on the post-test.

*R Bis is a correlation coefficient indicating the predictive ability of an item to the total score (See Walker and Lev, 1953, p. 261).

Item 2

Materials: Colored strip of paper pasted on an index card; three strings--2 slightly shorter than the strip, 1 slightly longer (Figure 6).

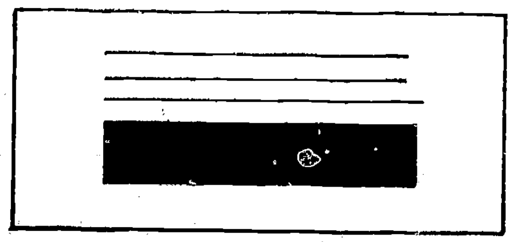

Figure 6

Materials for Item 2

Question: Can you find a string which is longer than this pink strip?

Results: See Table 9

Table 9

Results of Item 2

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 79 | 65 | - | 72 | 92 | 83 | 83 | 86 |
| R Bis | .69 | .52 | - | .62 | .49 | .76 | .28 | .46 |

This item was designed to examine the subjects' ability to compare lengths. It was suggested by one in a measurement test devised by Carey and Steffe (1968). To answer correctly it was necessary that the children place the strings right alongside the strip. Hopefully the strings were close enough in length that it was at least difficult to discriminate easily the longest one. If a child did simply pick out the longest string as the one longer than the strip he was asked to verify his selection--Can you show me for sure that that one is longer? What about these other strings, are they longer or shorter than the paper? Purely perceptual judgments without any actual manipulation of the materials were regarded as incorrect.

This did not prove to be an especially troublesome task for these children. Sixty-one, or 86%, of the children answered correctly on the posttest. Those who failed to do so were distributed among all three classes. Along with Item 1, this had also been a relatively easy item for the pretested subjects, answered by 72%.

Item 3

Materials: A straight and a wiggly line, drawn one under the other (with endpoints even) on heavy paper (Figure 7).

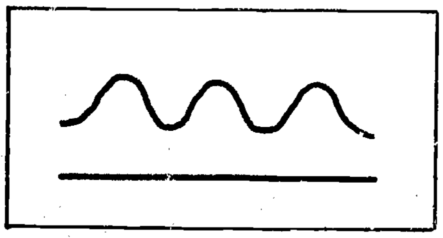

Figure 7

Materials for Item 3

Question: Which of these 2 lines is longer--the straight one or the wiggly one--or is the straight one just as long as the wiggly one?

Results: See Table 10.

Table 10

Results of Item 3

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 42 | 39 | - | 40 | 50 | 43 | 50 | 48 |
| R Bis | .46 | -.17 | - | .17 | .68 | .58 | .93 | .74 |

This is a Piagetian question, the first of several items based on ones described in The Child's Conception of Geometry. Piaget presented children with a straight wood stick and an undulating plasticine "snake," with the objects arranged side by side and the endpoints in exact alignment. His subjects were to make a judgment as to which was longer. Those who maintained the equality of the lines were shown what happened when the "snake" was straightened out and then returned to its original shape. He obtained correct responses from 90% of subjects over the age of 5-6, and 15% younger than 4-6. According to Piaget, incorrect answers occur because length is "judged in terms of [its] furthest extremities. The child notes that the endpoints of the two lines coincide and simply ignores the internal composition of those lines . . . the two lengths are correctly judged because children are aware of the intervals or segments which lie between the two extremities [p.94-95]."

This idea of looking at what lies between the endpoints was of course one of the components of length emphasized in the instruction.

The instruction, however, does not appear to have had a particularly marked effect on performance of this task. Neither was it one of the more difficult items. It was answered successfully by 40% of the children on the pretest and 48% on the posttest. It was the easiest of the conservation-related questions, this in accordance with the level stipulated by Piaget.

Item 4

Materials: 8 or 10 straight plastic ("count a ladder") pegs (Figure 8).

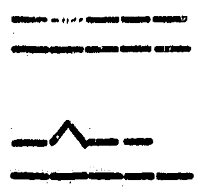

Figure 8

Materials for Item 4

Question: A. Two rows of 4 (or 5) pegs each, lined side by side so that endpoints are even.
Which one of these lines is longer, or is one line just as long as the other one?

B. One row modified by the addition of angles.
Which one of the lines is longer, or are they both the same?

Results: See Table 11.

Table 11

Results of Item 4

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 08 | 09 | - | 09 | 21 | 09 | 25 | 18 |
| R Bis | -.33 | .20 | - | -.08 | 1.14 | .29 | 1.07 | 1.02 |

A correct answer here means the realization on part B that both lines are still equal in length. Occasionally a child asserted that one line was longer in part A. In this case the pegs were manipulated until the two rows were seen as equal.

Piaget's version of this question involved the use of either matches or paper strips. Understanding was shown by 10% of his six-year-olds, and by half of those aged between 7-0 and 7-6. This task involves not only position of endpoints but also internal distortion of a segment (as compared to Item 6 for example).

A total of eleven children in the two training groups and two in the non-instructed group tackled the problem successfully on the posttest. This item was especially predictive of total score, with the highest overall posttest biserial correlation of any test question.

Item 5

Materials: Pipecleaner (Figure 9).

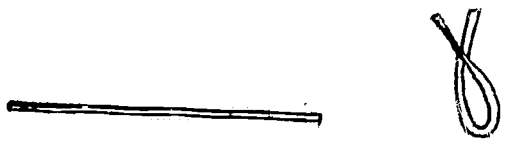

Figure 9

Materials for Item 5

Question: I have a pipecleaner here, see it? If I move it like this, is it the same length as before, or is it longer or shorter?

Results: See Table 12.

Table 12

Results of Item 5

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total Total |
| % Correct | 21 | 13 | - | 17 | 58 | 17 | 50 | 42 |
| R Bis | .32 | .61 | - | .45 | .69 | .47 | .85 | .78 |

In most of Piaget's conservation work, length included, judgments must be made as to the equivalence of two objects following a transformation of one of them. Yet in many respects these judgments require a comparison not only of two separate objects but also of one object in its original and in its transformed states. This concerns the principle of <u>identity</u> and need not involve a second object at all. Thus, it was decided to include one such identity problem. This item was used by Carey and Steffe (1968) in their test for concepts of measurement.

Indeed, these results do show some evidence that identity and equivalence questions are not of equal difficulty for young children. Further, this was one item which seems to have been particularly influenced by instruction. On the posttest fourteen, four, and twelve children respectively in the three groups answered this question correctly. This was an average of 54% for each of the training groups and 17% for the control. 17% had performed successfully on the pretests. Particularly after instruction, considerably more children were able to answer this item than they were the more typical (and more purely Piagetian) equivalence-conservation problems.

<u>Item 6</u>

Materials: Two plastic straws of equal length (Figure 10).

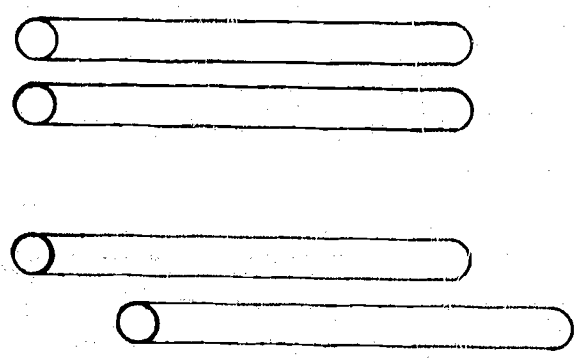

Figure 10

Materials for Item 6

Question: A. The straws placed side by side with endpoints even. Are these straws both just as long, or is one straw longer than the other?

B. Bottom straw pushed toward the right. Are they just as long now or is one longer than the other?

Results: See Table 13.

Table 13

Results of Item 6

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 0 | 0 | - | 0 | 17 | 13 | 25 | 18 |
| R Bis | 0 | 0 | - | 0 | .56 | .39 | .94 | .72 |

This is the classic conservation of length question. Young children who have not yet reached the conservation stage are thought by Piaget to base their judgment on position of the endpoints. Thus, they focus on only one of the ends, see that one object sticks out further, and maintain that it is longer. ". . . in comparing these lines, younger children are concerned exclusively with the order of their endpoints . . . . The key fact is that younger children do not take account of both ends simultaneously, which means that they are quite unconcerned with intervals of length between these endpoints

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[Piaget et al., 1960, p. 96]." Conservation is achieved with the realization that as the bottom stick is pushed forward, the space newly filled equals the space emptied and so length remains constant. This recognition comes, according to Piaget, around the age of seven.

Interestingly, this was the only item which no one was able to answer on the pretest; and it proved to be troublesome on the posttest, answered by 18% of the subjects. Posttest figures for this item are almost identical to those for Items 4 and 11. This is not surprising and at least points in the direction of consistency of response since these three items are quite closely related, being the three most clearly measuring "conservation" behavior.

Item 7

Materials: Two red paper strips, one under the other, staggered, glued to cardboard; two black markers (Figure 11).

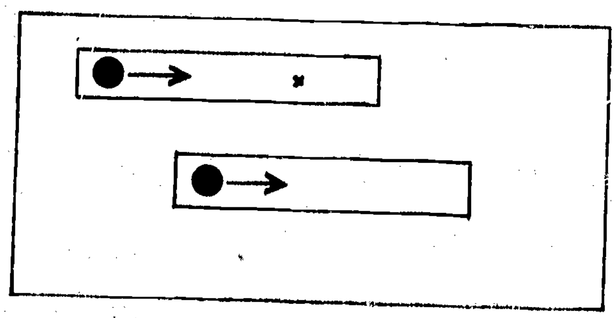

Figure 11

Materials for Item 7

Question: I'm going to move this little marker along this red paper--we'll pretend it's a car driving along a road. I'm going to make my car stop here. Now I want you to take your car and make it go for a ride that's just exactly as long as mine. Make it so that yours goes over just the same amount of road.

Results: See Table 14.

Table 14

Results of Item 7

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 04 | 13 | - | 09 | 08 | 13 | 04 | 08 |
| R Bis | .85 | 1.06 | - | .91 | .10 | .53 | .96 | .35 |

To answer this item correctly the child must take into account the different starting points of the "roads" and so move his "car" beyond the point where the first one stops in order that the lengths covered be made equal. A wrong response typically occurs when the subject places his marker directly underneath the top one, thereby moving it a shorter distance.

This question was an extremely difficult one, answered by only six children on the posttest. It was the only test item on which there was a decline in performance from the pretest. It is possible that there was some kind of communication problem, the children not quite understanding the nature of the task. They often moved their marker to a point immediately under the experimenter's even before the problem was fully explained. Then under repeated questioning they maintained that yes, their car had gone for a ride that was just as long.

This was a modification of a problem devised by Piaget (1960) and concerned with the subdivision of a straight line. He used lengths of string attached to nails and threaded with a bead. "The bead is a tram traveling along its track - - - and I want you to make your bead do a journey which is just as long as mine - - - [p. 129]." Children at early levels "fail to conceive of the length of a journey as an interval between the point of arrival and the point of departure but think of it only in terms of the former [p. 131]." This is a rather advanced task in the development of measurement behavior, probably not solved before the age of seven.

Item 8

Materials: Two unequal cardboard strips, attached on a base to form a "V", with a red circle at each end; two lengths of paper tickets, each equal to a corresponding arm of the "V" (Figure 12).

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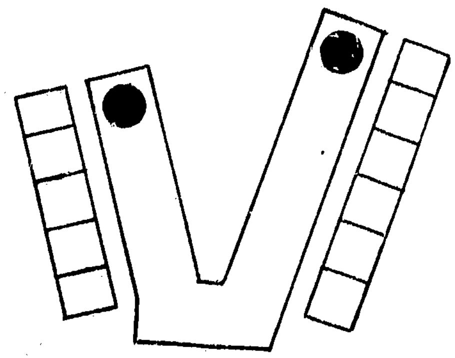


Figure 12

Materials for Item 8

Question: Can you use these tickets to tell me which circle is closer to you (with the "V" placed directly in front of the subject)?

Results: See Table 15.

Table 15

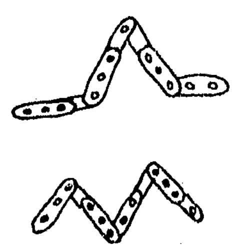
Results of Item 8

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 21 | 09 | - | 15 | 38 | 13 | 08 | 20 |
| R Bis | .92 | .81 | - | .90 | .85 | .53 | 1.11 | .80 |

Here the children are required to <u>represent</u> the arms of the "V" with the lines of tickets, thereby determining which circle is closer (or which arm is shorter). Although 14, or 20%, of the subjects were able to answer correctly on the posttest, this did not appear to the experimenters to be a particularly good item. It was clear all too often that the children did not know what was to be done with the tickets or how they were to be related to those red circles. Many did lay the tickets alongside the arms of the "V" but did not then compare the tickets, or indicate that a particular circle was closer because the corresponding line of tickets was shorter. An examination of the data, however, reveals that in spite of a high difficulty level this item was quite reliable in predicting total score. Children who did do well on this question generally achieved the high scores on the posttest. This was particularly true in the two training groups.

Item 9

Materials: Interlocking strips of plastic arranged to form two broken lines, equal in lenght but with angles such that one appears longer (Figure 13).



Item 13

Materials for Item 9

Question: Which of these lines is longer, or are they both just as long? Can you think of a way to tell for sure if one is longer than the other?

Results: See Table 16.

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Table 16

Results of Item 9

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 13 | 09 | - | 11 | 33 | 09 | 38 | 27 |
| R Bis | .55 | -.20 | - | .25 | .51 | .65 | .82 | .74 |

This was designed to get at the notion that length includes everything between the endpoints, that the path of the lines must be taken into consideration. The children were made aware that the configuration of these plastic lengths could be easily changed by bending them at their joints. Thus, it was intended that the subjects stretch them out straight to determine their comparative length. A purely perceptual judgment was not sufficient, since this always resulted in the false conclusion that the line was longer whose endpoints were further apart.

Ninteen, or 27%, of the children answered correctly on the posttest, 11% on the pretest. There is some indication that instruction was a significant variable (Table 3, $p < .07$), the successful subjects distributed among the three groups in the following manner: 8 in Group I, 2 in Group II, 9 in Group III.

Item 10

Materials: 3 lines drawn on a card: one straight; one curved equal to the straight one; one broken, longer than the other two. A string equal in length to the straight and curved lines ( Figure 14).

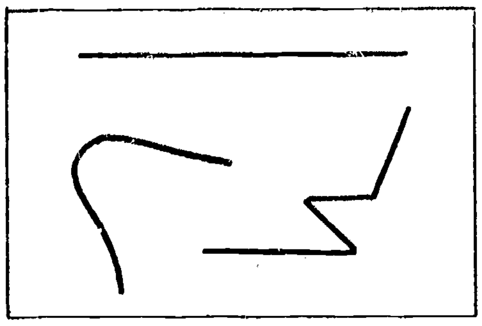

Figure 14

Materials for Item 10

Question: One of these lines is just as long as this straight one. Can you tell me which one it is-- the curved or the crooked one? You can use this piece of string to find out.

Results: See Table 17.

Table 17

Results of Item 10

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 58 | 52 | - | 55 | 83 | 52 | 58 | 65 |
| R Bis | .72 | .49 | - | .62 | .24 | .41 | .29 | .36 |

This is clearly a representation of length problem. Children were required to use the string and to use it properly, i.e. place it alongside the lines and have it follow the same pattern. Occasionally a child knew what had to be done but had trouble making the necessary manipulations. In this case he was helped by the experimenter.

It did not pose a particularly difficult problem for these subjects. 55% selected the right line on the pretest, 65% on the posttest. For all groups as a whole it was not very well predictive of total score.

Item 11

Materials: Two pipecleaners (Figure 15).

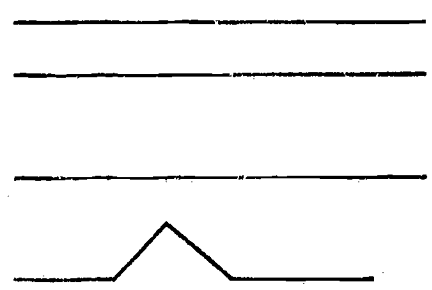

Figure 15

Materials for Item 11

Question: A. Placed one under the other, endpoints even. Which of these pipecleaners is longer, or is one just as long as the other?

B. One pipecleaner modified by the addition of an angle. Now which one of them is longer, or is one just as long as the other?

Results: See Table 18.

Table 18

Results of Item 11

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 08 | 09 | - | 09 | 29 | 0 | 21 | 17 |
| R Bis | .43 | .41 | - | .42 | .73 | 0 | 1.09 | .98 |

In the initial stages of preparation for this experiment the test included only the first 10 items. It was suggested, however, that the type of material used might be a factor in itself. That is, Items 4 and 5 differed not only in an identity-equivalence sense but also in the kind of material. The pegs are discontinuous, whereas the pipe-cleaner forms a continuous line. It was therefore decided to add two more items in which the other two combinations of these elements would be included. This question, then, is just like Item 4 except for the change in material.

Statistics parallel those for the earlier problem quite closely. For the three groups as a whole it was one of the more difficult questions (12 succeeded), but predictive ability was quite high.

Item 12

Materials: Plastic pegs (Figure 16).

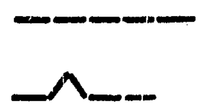

Figure 16

Materials for Item 12

Question: See, I have a line of pegs here. Now, I'm going to put it this way. Is it just as long now as it was before? Or is it longer or shorter this way?

Results: See Table 19.

Table 19

Results of Item 12

| | PRETEST | | | | POSTTEST | | | |
|---|---|---|---|---|---|---|---|---|
| | Grp. I | Grp. II | Grp. III | Total | Grp. I | Grp. II | Grp. III | Total |
| % Correct | 08 | 13 | - | 11 | 33 | 22 | 42 | 32 |
| R Bis | .24 | .91 | - | .59 | .76 | .73 | .87 | .81 |

Following the discussion of Item 11, this one can be seen to be the same as Item 5 except that the material is now discontinuous. Twenty-three (8, 5, and 10 in the three groups) subjects responded correctly on the posttest, indicating that perhaps the same question presented with a pipecleaner is somewhat easier than with pegs.

On the basis of these data, it is difficult to make any claims regarding specific effects on specific items. The training program appears to have generally increased total score without consistently increasing performance on given items. That is, children made overall gains, but these were due to different items for different children. Those items (2, 10) requiring manipulative measurement were handled more successfully than were the Piagetian questions. Tentatively, one might conclude further that a continuous line presents an easier context for length conservation than does a discontinuous one, and that an identity problem is easier for young children than an equivalence one.

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Table 3

2 x 2 x 2 Multivariate Analysis of Variance with Repeated Measures, with Training (A), Sex (B), Age (C), and Time Lapse between Pre- and Posttest (D): Groups I and II

BETWEEN: A EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.6007 | .1484 |
| Item 1 | 1 | .0185 | .1708 | .6817 |
| Item 2 | 1 | .3108 | 1.4449 | .2367 |
| Item 3 | 1 | .0482 | .1356 | .7147 |
| Item 4 | 1 | .0814 | .9142 | .3449 |
| Item 5 | 1 | 1.3945 | 8.6578 | .0055 |
| Item 6 | 1 | .0077 | .1087 | .7434 |
| Item 7 | 1 | .1084 | .8580 | .3601 |
| Item 8 | 1 | .7864 | 4.2481 | .0461 |
| Item 9 | 1 | .4750 | 2.7807 | .1035 |
| Item 10 | 1 | .8178 | 2.8230 | .1010 |
| Item 11 | 1 | .4872 | 4.7422 | .0356 |
| Item 12 | 1 | .0278 | .2456 | .6230 |

BETWEEN: B EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | .9399 | .5237 |
| Item 1 | 1 | .0001 | .0009 | .9762 |
| Item 2 | 1 | .0066 | .0309 | .8615 |
| Item 3 | 1 | .0160 | .0450 | .8331 |
| Item 4 | 1 | .1019 | 1.1438 | .2915 |
| Item 5 | 1 | .0799 | .4958 | .4856 |
| Item 6 | 1 | .0312 | .4405 | .5108 |
| Item 7 | 1 | .1128 | .8931 | .3505 |
| Item 8 | 1 | .0647 | .3497 | .5578 |
| Item 9 | 1 | .3594 | 2.1038 | .1550 |
| Item 10 | 1 | .5237 | 1.8077 | .1866 |
| Item 11 | 1 | .0952 | .9264 | .3418 |
| Item 12 | 1 | .0218 | .1927 | .6631 |

Table 3 (con't)

**BETWEEN: C EFFECT**

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.8431 | .0894 |
| Item 1 | 1 | 1.2804 | 11.8111 | .0015 |
| Item 2 | 1 | .0027 | .0125 | .9116 |
| Item 3 | 1 | .0184 | .0517 | .8214 |
| Item 4 | 1 | .0240 | .2697 | .6065 |
| Item 5 | 1 | .1113 | .6912 | .4109 |
| Item 6 | 1 | .0388 | .5474 | .4639 |
| Item 7 | 1 | .0058 | .0457 | .8319 |
| Item 8 | 1 | .0347 | .1876 | .6674 |
| Item 9 | 1 | 1.3707 | 8.0237 | .0073 |
| Item 10 | 1 | .0011 | .0039 | .9508 |
| Item 11 | 1 | .0100 | .0970 | .7571 |
| Item 12 | 1 | .3418 | 3.0167 | .0904 |

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**BETWEEN: AB EFFECT**

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.2326 | .3107 |
| Item 1 | 1 | .1793 | 1.6539 | .2061 |
| Item 2 | 1 | .7904 | 3.6740 | .0627 |
| Item 3 | 1 | .2264 | .6372 | .4296 |
| Item 4 | 1 | .2927 | 3.2866 | .0776 |
| Item 5 | 1 | .0226 | .1401 | .7103 |
| Item 6 | 1 | .0113 | .1599 | .6915 |
| Item 7 | 1 | .0569 | .4501 | .5063 |
| Item 8 | 1 | .0487 | .2629 | .6111 |
| Item 9 | 1 | .1219 | .7133 | .4035 |
| Item 10 | 1 | .0005 | .0018 | .9660 |
| Item 11 | 1 | .4007 | 3.8997 | .0555 |
| Item 12 | 1 | .3537 | 3.1210 | .0852 |

Table 3 (con't)

BETWEEN: AC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | .4734 | .9137 |
| Item 1 | 1 | .1245 | 1.1485 | .2905 |
| Item 2 | 1 | .1327 | .6166 | .4371 |
| Item 3 | 1 | .0323 | .0909 | .7647 |
| Item 4 | 1 | .1191 | 1.3369 | .2547 |
| Item 5 | 1 | .4059 | 2.5198 | .1205 |
| Item 6 | 1 | .0683 | .9633 | .3325 |
| Item 7 | 1 | .0258 | .2043 | .6538 |
| Item 8 | 1 | .0716 | .3865 | .5378 |
| Item 9 | 1 | .0110 | .0645 | .8009 |
| Item 10 | 1 | .0276 | .0952 | .7593 |
| Item 11 | 1 | .0321 | .3121 | .5796 |
| Item 12 | 1 | .0174 | .1532 | .6976 |

BETWEEN: BC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.3550 | .2447 |
| Item 1 | 1 | .2716 | 2.5056 | .1216 |
| Item 2 | 1 | .0181 | .0842 | .7732 |
| Item 3 | 1 | .2260 | .6362 | .4300 |
| Item 4 | 1 | .0161 | .1803 | .6735 |
| Item 5 | 1 | .4845 | 3.0079 | .0908 |
| Item 6 | 1 | .0353 | .4972 | .4850 |
| Item 7 | 1 | .0055 | .0439 | .8352 |
| Item 8 | 1 | 1.2102 | 6.5376 | .0146 |
| Item 9 | 1 | .0801 | .4689 | .4976 |
| Item 10 | 1 | .0557 | .1922 | .6636 |
| Item 11 | 1 | .0231 | .2251 | .6379 |
| Item 12 | 1 | .3705 | 3.2698 | .0783 |

Table 3 (con't)

BETWEEN: ABC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.4327 | .2095 |
| Item 1 | 1 | .0042 | .0388 | .8450 |
| Item 2 | 1 | .0079 | .0369 | .8487 |
| Item 3 | 1 | .1957 | .5508 | .4625 |
| Item 4 | 1 | .1040 | 1.1674 | .2866 |
| Item 5 | 1 | .0279 | .1729 | .6799 |
| Item 6 | 1 | .0208 | .2933 | .5912 |
| Item 7 | 1 | .3952 | 3.1282 | .0848 |
| Item 8 | 1 | .2239 | 1.2093 | .2783 |
| Item 9 | 1 | .0257 | .1506 | .7001 |
| Item 10 | 1 | .4877 | 1.6835 | .2021 |
| Item 11 | 1 | .1576 | 1.5339 | .2230 |
| Item 12 | 1 | .0007 | .0059 | .9391 |

BETWEEN: ERROR (for all effects)

| Source | df | MS |
|---|---|---|
| Item 1 | 39 | .1084 |
| Item 2 | 39 | .2151 |
| Item 3 | 39 | .3552 |
| Item 4 | 39 | .0891 |
| Item 5 | 39 | .1611 |
| Item 6 | 39 | .0709 |
| Item 7 | 39 | .1264 |
| Item 8 | 39 | .1851 |
| Item 9 | 39 | .1708 |
| Item 10 | 39 | .2897 |
| Item 11 | 39 | .1027 |
| Item 12 | 39 | .1133 |

Table 3 (con't)

BETWEEN: TOTAL SCORE (univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| A | 1 | 30.0642 | 9.2898 | .0042 |
| B | 1 | 3.7054 | 1.1449 | .2912 |
| C | 1 | 2.8658 | .8855 | .3525 |
| AB | 1 | 19.6425 | 6.0695 | .0183 |
| AC | 1 | .2398 | .0741 | .7870 |
| BC | 1 | 9.1581 | 2.8298 | .1006 |
| ABC | 1 | .0851 | .0263 | .8721 |
| ERROR | 39 | 3.2363 | | |

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WITHIN: D EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 2.7624 | .0131 |
| Item 1 | 1 | 1.2872 | 11.5113 | .0016 |
| Item 2 | 1 | .5213 | 4.5957 | .0384 |
| Item 3 | 1 | .0957 | .5002 | .4837 |
| Item 4 | 1 | .0957 | .8347 | .3666 |
| Item 5 | 1 | 1.0638 | 5.6544 | .0225 |
| Item 6 | 1 | .5213 | 7.3518 | .0100 |
| Item 7 | 1 | .0106 | .2152 | .6453 |
| Item 8 | 1 | .2660 | 2.1350 | .1520 |
| Item 9 | 1 | .2660 | 3.5818 | .0659 |
| Item 10 | 1 | .3830 | 2.1791 | .1480 |
| Item 11 | 1 | .0957 | 1.2418 | .2720 |
| Item 12 | 1 | .6808 | 3.4447 | .0711 |

Table 3 (con't)

WITHIN: AD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.8866 | .0815 |
| Item 1 | 1 | .0162 | .1449 | .7055 |
| Item 2 | 1 | .0140 | .1239 | .7268 |
| Item 3 | 1 | .0093 | .0487 | .8265 |
| Item 4 | 1 | .0918 | .7999 | .3767 |
| Item 5 | 1 | .6454 | 3.4305 | .0716 |
| Item 6 | 1 | .0077 | .1087 | .7434 |
| Item 7 | 1 | .0102 | .2063 | .6523 |
| Item 8 | 1 | .0891 | .7154 | .4029 |
| Item 9 | 1 | .2549 | 3.4326 | .0716 |
| Item 10 | 1 | .3670 | 2.0883 | .1565 |
| Item 11 | 1 | .5120 | 6.6412 | .0139 |
| Item 12 | 1 | .1561 | .7898 | .3797 |

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WITHIN: BD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.2977 | .2739 |
| Item 1 | 1 | .1088 | .9729 | .3301 |
| Item 2 | 1 | .0620 | .5470 | .4640 |
| Item 3 | 1 | .3405 | 1.7787 | .1901 |
| Item 4 | 1 | .0249 | .2168 | .6442 |
| Item 5 | 1 | .1527 | .8117 | .3732 |
| Item 6 | 1 | .0312 | .4405 | .5108 |
| Item 7 | 1 | .1108 | 2.2418 | .1424 |
| Item 8 | 1 | .0392 | .3149 | .5780 |
| Item 9 | 1 | .0371 | .5002 | .4837 |
| Item 10 | 1 | .0111 | .0629 | .8034 |
| Item 11 | 1 | .3221 | 4.1771 | .0478 |
| Item 12 | 1 | .0227 | .1151 | .7363 |

Table 3 (con't)

WITHIN: CD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.4710 | .1938 |
| Item 1 | 1 | .3848 | 3.4414 | .0712 |
| Item 2 | 1 | .0659 | .5814 | .4504 |
| Item 3 | 1 | .0688 | .3593 | .5524 |
| Item 4 | 1 | .1131 | .9864 | .3268 |
| Item 5 | 1 | .3639 | 1.9341 | .1722 |
| Item 6 | 1 | .0388 | .5474 | .4639 |
| Item 7 | 1 | .0741 | 1.4987 | .2283 |
| Item 8 | 1 | .0978 | .7849 | .3811 |
| Item 9 | 1 | .0064 | .0863 | .7706 |
| Item 10 | 1 | .0002 | .0011 | .9740 |
| Item 11 | 1 | .0507 | .6581 | .4222 |
| Item 12 | 1 | .0559 | .2830 | .5978 |

WITHIN: ABD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | .8582 | .5950 |
| Item 1 | 1 | .1615 | 1.4444 | .2367 |
| Item 2 | 1 | .1237 | 1.0906 | .3028 |
| Item 3 | 1 | .0150 | .0783 | .7811 |
| Item 4 | 1 | .3460 | 3.0160 | .0904 |
| Item 5 | 1 | .0095 | .0503 | .8237 |
| Item 6 | 1 | .0113 | .1599 | .6915 |
| Item 7 | 1 | .0120 | .2432 | .6247 |
| Item 8 | 1 | .1181 | .9483 | .3362 |
| Item 9 | 1 | .0337 | .4538 | .5046 |
| Item 10 | 1 | .1015 | .5773 | .4520 |
| Item 11 | 1 | .0531 | .6886 | .4118 |
| Item 12 | 1 | .1416 | .7163 | .4026 |

Table 3 (con't)

WITHIN: ACD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.6490 | .1343 |
| Item 1 | 1 | .1606 | 1.4364 | .2380 |
| Item 2 | 1 | .2296 | 2.0247 | .1628 |
| Item 3 | 1 | .1303 | .6808 | .4144 |
| Item 4 | 1 | .0013 | .0115 | .9152 |
| Item 5 | 1 | .0060 | .0321 | .8588 |
| Item 6 | 1 | .0683 | .9633 | .3325 |
| Item 7 | 1 | .2909 | 5.8844 | .0201 |
| Item 8 | 1 | .0003 | .0022 | .9625 |
| Item 9 | 1 | .0049 | .0655 | .7993 |
| Item 10 | 1 | .6508 | 3.7032 | .0617 |
| Item 11 | 1 | .2786 | 3.6141 | .0648 |
| Item 12 | 1 | .0506 | .2560 | .6158 |

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WITHIN: BCD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | 1.8229 | .0933 |
| Item 1 | 1 | .0089 | .0799 | .7790 |
| Item 2 | 1 | .0523 | .4614 | .5010 |
| Item 3 | 1 | .3561 | 1.8604 | .1804 |
| Item 4 | 1 | .3328 | 2.9013 | .0965 |
| Item 5 | 1 | .0279 | .1485 | .7021 |
| Item 6 | 1 | .0353 | .4972 | .4850 |
| Item 7 | 1 | .0615 | 1.2451 | .2714 |
| Item 8 | 1 | .0265 | .2131 | .6470 |
| Item 9 | 1 | .0006 | .0085 | .9269 |
| Item 10 | 1 | .4922 | 2.8007 | .1023 |
| Item 11 | 1 | .1618 | 2.0980 | .1555 |
| Item 12 | 1 | .0326 | .1650 | .6869 |

Table 3 (con't)

WITHIN: ABCD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,28 | | .3905 | .9557 |
| Item 1 | 1 | .0108 | .0962 | .7582 |
| Item 2 | 1 | .0074 | .0650 | .8001 |
| Item 3 | 1 | .0190 | .0991 | .7546 |
| Item 4 | 1 | .0208 | .1813 | .6726 |
| Item 5 | 1 | .3932 | 2.0900 | .1563 |
| Item 6 | 1 | .0208 | .2933 | .5912 |
| Item 7 | 1 | .0021 | .0416 | .8394 |
| Item 8 | 1 | .0046 | .0372 | .8482 |
| Item 9 | 1 | .0006 | .0080 | .9294 |
| Item 10 | 1 | .1401 | .7972 | .3775 |
| Item 11 | 1 | .0190 | .2460 | .6227 |
| Item 12 | 1 | .1512 | .7651 | .3871 |

WITHIN: ERROR (for all effects)

| Source | df | MS |
|---|---|---|
| Item 1 | 39 | .1112 |
| Item 2 | 39 | .1134 |
| Item 3 | 39 | .1914 |
| Item 4 | 39 | .1147 |
| Item 5 | 39 | .1881 |
| Item 6 | 39 | .0709 |
| Item 7 | 39 | .0494 |
| Item 8 | 39 | .1246 |
| Item 9 | 39 | .0743 |
| Item 10 | 39 | .1757 |
| Item 11 | 39 | .0771 |
| Item 12 | 39 | .1976 |

Table 3 (con't)

WITHIN: TOTAL SCORE (univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| D | 1 | 50.6480 | 23.6580 | .0001 |
| AD | 1 | 13.4369 | 6.2764 | .0166 |
| BD | 1 | 9.4942 | 4.4348 | .0418 |
| CD | 1 | 3.0698 | 1.4339 | .2384 |
| ABD | 1 | .1182 | .0552 | .8155 |
| ACD | 1 | 1.6216 | .7575 | .3895 |
| BCD | 1 | .0005 | .0002 | .9883 |
| ABCD | 1 | .6150 | .2873 | .5951 |
| ERROR | 39 | 2.1408 | | |

Table 4

2 x 2 x 3 Multivariate Analysis of Variance, with Pretest (A), Sex (B), and Age (C): Groups I and III

A EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,25 | | 1.2860 | .2862 |
| Item 1 | 1 | .0000 | .0000 | 1.0000 |
| Item 2 | 1 | .0833 | .6914 | .4112 |
| Item 3 | 1 | .0000 | .0000 | 1.0000 |
| Item 4 | 1 | .0208 | .1281 | .7226 |
| Item 5 | 1 | .0833 | .3140 | .5788 |
| Item 6 | 1 | .0833 | .4467 | .5082 |
| Item 7 | 1 | .0208 | .3075 | .5827 |
| Item 8 | 1 | 1.0208 | 6.7226 | .0137 |
| Item 9 | 1 | .0208 | .0928 | .7625 |
| Item 10 | 1 | .7500 | 3.6377 | .0645 |
| Item 11 | 1 | .0833 | .4982 | .4849 |
| Item 12 | 1 | .0833 | .4173 | .5224 |

B EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,25 | | .7645 | .6793 |
| Item 1 | 1 | .0595 | 1.3075 | .2604 |
| Item 2 | 1 | .0214 | .1778 | .6758 |
| Item 3 | 1 | .0857 | .3504 | .5576 |
| Item 4 | 1 | .0149 | .0915 | .7641 |
| Item 5 | 1 | .1167 | .4395 | .5116 |
| Item 6 | 1 | .1167 | .6253 | .4343 |
| Item 7 | 1 | .0054 | .0791 | .7802 |
| Item 8 | 1 | .0149 | .0980 | .7561 |
| Item 9 | 1 | .3149 | 1.4024 | .2441 |
| Item 10 | 1 | .0595 | .2887 | .5944 |
| Item 11 | 1 | .3429 | 2.0496 | .1609 |
| Item 12 | 1 | .0214 | .1073 | .7452 |

Table 4 (con't)

C EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 24,50 | | .8935 | .6084 |
| Item 1 | 2 | .0189 | .4153 | .6633 |
| Item 2 | 2 | .1843 | 1.5290 | .2305 |
| Item 3 | 2 | .2707 | 1.1067 | .3417 |
| Item 4 | 2 | .4182 | 2.5708 | .0905 |
| Item 5 | 2 | .1181 | .4449 | .6444 |
| Item 6 | 2 | .0373 | .2001 | .8196 |
| Item 7 | 2 | .0260 | .3832 | .6845 |
| Item 8 | 2 | .2257 | 1.4861 | .2398 |
| Item 9 | 2 | .3586 | 1.5970 | .2166 |
| Item 10 | 2 | .0069 | .0333 | .9674 |
| Item 11 | 2 | .2937 | 1.7555 | .1873 |
| Item 12 | 2 | .0734 | .3675 | .6951 |

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AB EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,25 | | .7421 | .6994 |
| Item 1 | 1 | .0003 | .0066 | .9360 |
| Item 2 | 1 | .0698 | .5788 | .4518 |
| Item 3 | 1 | .0577 | .2358 | .6302 |
| Item 4 | 1 | .7717 | 4.7445 | .0361 |
| Item 5 | 1 | .0802 | .3021 | .5860 |
| Item 6 | 1 | .0065 | .0348 | .8531 |
| Item 7 | 1 | .0418 | .6171 | .4373 |
| Item 8 | 1 | .2752 | 1.8124 | .1867 |
| Item 9 | 1 | .0923 | .4112 | .5255 |
| Item 10 | 1 | .0181 | .0878 | .7687 |
| Item 11 | 1 | .3675 | 2.1967 | .1471 |
| Item 12 | 1 | .2426 | 1.2147 | .2778 |

Table 4 (con't)

AC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 24,50 | | .8330 | .6807 |
| Item 1 | 2 | .0439 | .9648 | .3908 |
| Item 2 | 2 | .0260 | .2158 | .8070 |
| Item 3 | 2 | .6337 | 2.5907 | .0889 |
| Item 4 | 2 | .0438 | .2692 | .7656 |
| Item 5 | 2 | .1072 | .4039 | .6708 |
| Item 6 | 2 | .0964 | .5168 | .6008 |
| Item 7 | 2 | .0837 | 1.2362 | .3026 |
| Item 8 | 2 | .0189 | .1247 | .8832 |
| Item 9 | 2 | .5850 | 2.6054 | .0878 |
| Item 10 | 2 | .5279 | 2.5605 | .0913 |
| Item 11 | 2 | .0343 | .2050 | .8157 |
| Item 12 | 2 | .2070 | 1.0364 | .3651 |

BC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 24,50 | | 1.0452 | .4339 |
| Item 1 | 2 | .0150 | .3298 | .7213 |
| Item 2 | 2 | .0265 | .2200 | .8036 |
| Item 3 | 2 | .0087 | .0355 | .9652 |
| Item 4 | 2 | .1388 | .8533 | .4345 |
| Item 5 | 2 | .7606 | 2.8656 | .0701 |
| Item 6 | 2 | .0430 | .2306 | .7953 |
| Item 7 | 2 | .0320 | .4728 | .6271 |
| Item 8 | 2 | .1782 | 1.1733 | .3209 |
| Item 9 | 2 | .0404 | .1799 | .8361 |
| Item 10 | 2 | .1476 | .7161 | .4955 |
| Item 11 | 2 | .6209 | 3.7114 | .0343 |
| Item 12 | 1 | 1.0858 | 5.4373 | .0087 |

Table 4 (con't)

ABC EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 24,50 | | .8771 | .6280 |
| Item 1 | 2 | .0311 | .6840 | .5111 |
| Item 2 | 2 | .1315 | 1.0909 | .3468 |
| Item 3 | 2 | .6124 | 2.5039 | .0960 |
| Item 4 | 2 | .3074 | 1.8897 | .1659 |
| Item 5 | 2 | .0546 | .2055 | .8152 |
| Item 6 | 2 | .3200 | 1.7150 | .1944 |
| Item 7 | 2 | .0111 | .1634 | .8500 |
| Item 8 | 2 | .4280 | 2.8185 | .0730 |
| Item 9 | 2 | .2499 | 1.1129 | .3397 |
| Item 10 | 2 | .1510 | .7325 | .4878 |
| Item 11 | 2 | .1432 | .8563 | .4333 |
| Item 12 | 2 | .4908 | 2.4576 | .0999 |

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ERROR (for all effects)

| Source | df | MS |
|---|---|---|
| Item 1 | 36 | .0455 |
| Item 2 | 36 | .1205 |
| Item 3 | 36 | .2446 |
| Item 4 | 36 | .1627 |
| Item 5 | 36 | .2654 |
| Item 6 | 36 | .1866 |
| Item 7 | 36 | .0677 |
| Item 8 | 36 | .1519 |
| Item 9 | 36 | .2245 |
| Item 10 | 36 | .2062 |
| Item 11 | 36 | .1673 |
| Item 12 | 36 | .1997 |

Table 4 (con't)

TOTAL SCORE (univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| A | 1 | 4.0833 | .7494 | .3924 |
| B | 1 | 4.4024 | .8080 | .3747 |
| C | 2 | 10.5309 | 1.9327 | .1595 |
| AB | 1 | 14.7017 | 2.6982 | .1092 |
| AC | 2 | 12.5449 | 2.3023 | .1146 |
| BC | 2 | 12.9472 | 2.3762 | .1074 |
| ABC | 2 | 16.2638 | 2.9849 | .0632 |
| ERROR | 36 | 5.4488 | | |

Table 5

2 x 2 Multivariate Analysis of Variance with Repeated Measures, with Sex of Subject (A), Sex of Experimenter (B), and Time Lapse between Pre- and Posttest (D): Groups I and II

BETWEEN: A EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .7951 | .6523 |
| Item 1 | 1 | .0002 | .0013 | .9715 |
| Item 2 | 1 | .0045 | .0206 | .8867 |
| Item 3 | 1 | .0146 | .0445 | .8340 |
| Item 4 | 1 | .1066 | 1.1655 | .2864 |
| Item 5 | 1 | .0980 | .4935 | .4862 |
| Item 6 | 1 | .0304 | .4933 | .4863 |
| Item 7 | 1 | .1186 | .9428 | .3370 |
| Item 8 | 1 | .0769 | .3514 | .5565 |
| Item 9 | 1 | .3808 | 1.8790 | .1776 |
| Item 10 | 1 | .5577 | 1.9333 | .1716 |
| Item 11 | 1 | .1066 | .9489 | .3355 |
| Item 12 | 1 | .0231 | .1843 | .6699 |

BETWEEN: B EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .9246 | .5350 |
| Item 1 | 1 | .1182 | .8499 | .3618 |
| Item 2 | 1 | .2295 | 1.0486 | .3116 |
| Item 3 | 1 | .3918 | 1.1953 | .2804 |
| Item 4 | 1 | .0098 | .1074 | .7448 |
| Item 5 | 1 | .0599 | .3018 | .5857 |
| Item 6 | 1 | .2946 | 4.7789 | .0344 |
| Item 7 | 1 | .0725 | .5766 | .4518 |
| Item 8 | 1 | .1122 | .5129 | .4778 |
| Item 9 | 1 | .0097 | .0481 | .8276 |
| Item 10 | 1 | .2454 | .8508 | .3615 |
| Item 11 | 1 | .2715 | 2.4176 | .1274 |
| Item 12 | 1 | .0562 | .4497 | .5070 |

Table 5 (con't)

BETWEEN: AB EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .4556 | .9258 |
| Item 1 | 1 | .0050 | .0363 | .8499 |
| Item 2 | 1 | .0131 | .0601 | .8076 |
| Item 3 | 1 | .1149 | .3504 | .5570 |
| Item 4 | 1 | .1648 | 1.8020 | .1866 |
| Item 5 | 1 | .1121 | .5647 | .4565 |
| Item 6 | 1 | .0024 | .0385 | .8455 |
| Item 7 | 1 | .0400 | .3178 | .5759 |
| Item 8 | 1 | .0654 | .2990 | .5874 |
| Item 9 | 1 | .0009 | .0043 | .9482 |
| Item 10 | 1 | .0058 | .0201 | .8880 |
| Item 11 | 1 | .0056 | .0502 | .8238 |
| Item 12 | 1 | .0807 | .6437 | .4268 |

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BETWEEN: ERROR (for all effects)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Item 1 | 43 | .1391 | | |
| Item 2 | 43 | .2189 | | |
| Item 3 | 43 | .3278 | | |
| Item 4 | 43 | .0914 | | |
| Item 5 | 43 | .1986 | | |
| Item 6 | 43 | .0617 | | |
| Item 7 | 43 | .1257 | | |
| Item 8 | 43 | .2188 | | |
| Item 9 | 43 | .2027 | | |
| Item 10 | 43 | .2885 | | |
| Item 11 | 43 | .1123 | | |
| Item 12 | 43 | .1254 | | |

Table 5 (con't)

BETWEEN: TOTAL SCORE (univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| A | 1 | 4.2681 | .9922 | .3248 |
| B | 1 | 2.6102 | .6068 | .4403 |
| AB | 1 | .1276 | .0297 | .8641 |
| ERROR | 43 | 4.3016 | | |

WITHIN: D EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | 2.5156 | .0186 |
| Item 1 | 1 | 1.2872 | 11.0740 | .0019 |
| Item 2 | 1 | .5213 | 4.7062 | .0357 |
| Item 3 | 1 | .0957 | .5207 | .4745 |
| Item 4 | 1 | .0957 | .7825 | .3814 |
| Item 5 | 1 | 1.0638 | 5.4703 | .0241 |
| Item 6 | 1 | .5213 | 8.4544 | .0058 |
| Item 7 | 1 | .0106 | .1937 | .6621 |
| Item 8 | 1 | .2660 | 2.3206 | .1350 |
| Item 9 | 1 | .2660 | 3.6236 | .0637 |
| Item 10 | 1 | .3830 | 1.9540 | .1694 |
| Item 11 | 1 | .0957 | 1.0179 | .3187 |
| Item 12 | 1 | .6808 | 4.1469 | .0479 |

Table 5 (con't)

WITHIN: AD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .9358 | .5252 |
| Item 1 | 1 | .1066 | .9168 | .3437 |
| Item 2 | 1 | .0605 | .5461 | .4640 |
| Item 3 | 1 | .3432 | 1.8664 | .1790 |
| Item 4 | 1 | .0274 | .2237 | .6387 |
| Item 5 | 1 | .1692 | .8703 | .3561 |
| Item 6 | 1 | .0304 | .4933 | .4863 |
| Item 7 | 1 | .1125 | 2.0485 | .1596 |
| Item 8 | 1 | .0423 | .3692 | .5467 |
| Item 9 | 1 | .0423 | .5765 | .4519 |
| Item 10 | 1 | .0146 | .0744 | .7864 |
| Item 11 | 1 | .3432 | 3.6485 | .0629 |
| Item 12 | 1 | .0259 | .1578 | .6932 |

WITHIN: BD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .8474 | .6042 |
| Item 1 | 1 | .0988 | .8501 | .3617 |
| Item 2 | 1 | .0106 | .0957 | .7586 |
| Item 3 | 1 | .0789 | .4292 | .5159 |
| Item 4 | 1 | .0940 | .7681 | .3857 |
| Item 5 | 1 | .3807 | 1.9578 | .1690 |
| Item 6 | 1 | .2946 | 4.7789 | .0344 |
| Item 7 | 1 | .0072 | .1319 | .7183 |
| Item 8 | 1 | .0971 | .8473 | .3625 |
| Item 9 | 1 | .0110 | .1500 | .7005 |
| Item 10 | 1 | .1661 | .8477 | .3624 |
| Item 11 | 1 | .0055 | .0586 | .8100 |
| Item 12 | 1 | .6966 | 4.2429 | .0456 |

Table 5 (con't)

WITHIN: ABD EFFECT

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,32 | | .7428 | .7006 |
| Item 1 | 1 | .0091 | .0783 | .7810 |
| Item 2 | 1 | .1448 | 1.3074 | .2592 |
| Item 3 | 1 | .0762 | .4144 | .5232 |
| Item 4 | 1 | .0214 | .1745 | .6783 |
| Item 5 | 1 | .0238 | .1223 | .7283 |
| Item 6 | 1 | .0024 | .0385 | .8455 |
| Item 7 | 1 | .0085 | .1553 | .6955 |
| Item 8 | 1 | .1664 | 1.4520 | .2348 |
| Item 9 | 1 | .0247 | .3371 | .5646 |
| Item 10 | 1 | .0085 | .0435 | .8358 |
| Item 11 | 1 | .0111 | .1184 | .7325 |
| Item 12 | 1 | .5368 | 3.2695 | .0776 |

WITHIN: ERROR (for all effects)

| Source | df | MS |
|---|---|---|
| Item 1 | 43 | .1162 |
| Item 2 | 43 | .1108 |
| Item 3 | 43 | .1839 |
| Item 4 | 43 | .1224 |
| Item 5 | 43 | .1945 |
| Item 6 | 43 | .0617 |
| Item 7 | 43 | .0549 |
| Item 8 | 43 | .1146 |
| Item 9 | 43 | .0734 |
| Item 10 | 43 | .1960 |
| Item 11 | 43 | .0941 |
| Item 12 | 43 | .1642 |

Table 5 (con't)

WITHIN: TOTAL SCORE (univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| D | 1 | 50.6480 | 23.3796 | .0001 |
| AD | 1 | 10.0802 | 4.6531 | .0367 |
| BD | 1 | 4.5306 | 2.0914 | .1554 |
| ABD | 1 | 4.0861 | 1.8862 | .1768 |
| ERROR | 43 | 2.1663 | | |

Table 6

Multivariate Analysis of Variance with Sex of Experimenter the Single Factor and Six Levels of this Factor (Six Different Experimenters): Groups I, II, and III.

CONTRAST #1 (SEX)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 12,54 | | 1.7068 | .0911 |
| Item 1 | 1 | .0030 | .0701 | .7921 |
| Item 2 | 1 | .0686 | .5548 | .4591 |
| Item 3 | 1 | .2076 | .8000 | .3745 |
| Item 4 | 1 | .0056 | .0368 | .8485 |
| Item 5 | 1 | .4397 | 1.7987 | .1846 |
| Item 6 | 1 | .1665 | 1.1202 | .2938 |
| Item 7 | 1 | .0118 | .1551 | .6951 |
| Item 8 | 1 | .0046 | .0301 | .8628 |
| Item 9 | 1 | .1807 | .9007 | .3462 |
| Item 10 | 1 | .2850 | 1.4784 | .2285 |
| Item 11 | 1 | .0006 | .0040 | .9495 |
| Item 12 | 1 | .7578 | 3.6639 | .0601 |

CONTRASTS #2, 3, 4, 5 (EXPERIMENTER WITHIN SEX)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| Multivariate | 48,210 | | 1.8063 | .0025 |
| Item 1 | 4 | .0309 | .7309 | .5742 |
| Item 2 | 4 | .1226 | .9922 | .4183 |
| Item 3 | 4 | .1599 | .6161 | .6526 |
| Item 4 | 4 | .1829 | 1.2029 | .3182 |
| Item 5 | 4 | .2487 | 1.0172 | .4052 |
| Item 6 | 4 | .1978 | 1.3307 | .2681 |
| Item 7 | 4 | .1295 | 1.6959 | .1617 |
| Item 8 | 4 | .3119 | 2.0297 | .1006 |
| Item 9 | 4 | .1740 | .8672 | .4885 |
| Item 10 | 4 | .8451 | 4.3832 | .0034 |
| Item 11 | 4 | .2156 | 1.5387 | .2015 |
| Item 12 | 4 | .3368 | 1.6283 | .1778 |

Table 6 (con't)

ERROR (for all contrasts)

| Source | df | MS |
|---|---|---|
| Item 1 | 65 | .0423 |
| Item 2 | 65 | .1236 |
| Item 3 | 65 | .2596 |
| Item 4 | 65 | .1520 |
| Item 5 | 65 | .2445 |
| Item 6 | 65 | .1486 |
| Item 7 | 65 | .0764 |
| Item 8 | 65 | .1537 |
| Item 9 | 65 | .2006 |
| Item 10 | 65 | .1928 |
| Item 11 | 65 | .1401 |
| Item 12 | 65 | .2068 |

TOTAL SCORE (Univariate)

| Source | df | MS | F | p< |
|---|---|---|---|---|
| #1 | 1 | 3.3098 | .5291 | .4696 |
| #2, 3, 4, 5 | 4 | 1.1224 | .1794 | .9483 |
| ERROR | 65 | 6.2553 | | |

## Chapter IV

## GENERAL DISCUSSION

Undoubtedly any Piagetian experiment reveals the difficulties that have made conservation such a debated topic. This one is no exception. On the one hand it is perfectly clear that Piaget has indeed described a phenomenon of children's thinking, and a phenomenon that is not unique to his own subjects in his own carefully prescribed situations. The skeptical investigator, concerned over lack of controls, broad sample, and other experimental data, need only approach some young children with Piaget's questions to find that the answers he receives are most likely already recorded somewhere in Piaget's body of writing. Repeated studies have confirmed the presence of the various stages and levels and sequences outlined by Piaget; and repeated efforts have generally brought the conclusion that, whatever the particular case, it <u>is</u> difficult to force or convince or persuade or teach these stubborn youngsters to abandon their non-conservational notions.

In many ways the results reported here do simply further attest to the presence of the phenomenon and the difficulty in influencing it. No matter how one delves into the data, an average score of 6 (or 50%) as the attainment of the highest group certainly does not indicate real comprehension of the concepts involved. Over and over again children stated quite positively that yes, the botton straw was longer, no, now the top one, well, now they're the same again.

Then what is all the fuss about? Piaget is right! Yes, in so far as he has described children's reactions to his questioning. It is his penchant for interpretation, however, that has brought the sudden flood of attempts to "explain" conservation; for it is one thing to discover a child's misunderstanding, quite another to claim that it cannot be remedied without a major but undetermined change in mental structure. Can a mistake about invariance in the face of transformation possibly relate to "a necessary condition of all experience and all reasoning . . . a necessary condition for all rational activity [Piaget, 1941, p. 3.]?"

Such a statement was bound to call forth evidence putting conservation in a less mystical, more operational and therefore more modifiable framework. And in seeking alternative explanations, what the training literature has done is to point out the serious difficulties in any interpretation. These problems stem from the fact that the results of a conservation experiment are terribly confounded by innumerable factors, which invariably influence children's responses but which are not always considered as relevant by Piaget (or by many of his experimenter-followers, for that matter).

A host of relatively minor of these interfering variables could be listed. There is the question of the particular material used and, more generally, the particular content of the task as presented to the child. Beads in piles, dolls in beds, chips in a machine have all been used to assess number conservation. Theoretically such variance in procedure should make no difference, but practically it very well might. In this study, seven more children solved a conservation-identity problem with a pipecleaner than with pegs. Furthermore, the identity questions were handled considerably more successfully than were the equivalence ones, indicating that the exact format of the experimental task probably influences children's responses. Even more specific is the precise manipulation and who carries it out. It has been suggested that the subject tends to respond to whichever set is the one undergoing the transformation (Zimiles, 1963); in such a case, Item 6 for example, the "nonconserver's" answer would depend partially on whether it is the top or the bottom straw which is moved. And perhaps the answer would be different yet if the subject himself performed the various operations. Age is always of concern in a Piagetian experiment. But what about sex? Here, girls outperformed boys. How about IQ? Or the child's repertoire of skills, such as counting, which he brings to the situation?

Aside from these elements is the one which has inspired the most speculation and the most research, and is the one which has become most central to the issue of conservation. This is the whole matter of language. It includes any number of related questions. Bruner has investigated the role of language as a mediator, as a necessary aid in overcoming the misleading perceptual cues. Gruen pointed out the importance of language in the very definition of a conserving response. Whereas many researchers consider the verbal elements of an experiment to be an interference which must in some way be overcome, the Geneva school will accept a response as conserving only if it can be stated verbally.

Even more basic to the issue of language and conservation is the children's understanding of terms. Many studies have been conducted specifically to examine whether in fact the verbal nature of the task stands in the way of correct performance. Many more have accounted for this variable in their design by attempting to make sure that the children do grasp the terms used.

This experiment, too, proceeded from a language framework; the training program was in essence a mathematical explanation of the term "length," a delineation of those components which Piaget has made the basis of his work with length conservation. Indeed, in his monograph, "The Ontogeny of Certain Logical Operations," Braine argued that the very use of the word "length"

> presupposes comprehension of the additive operation involved in measurement, since the length of a line which is not straight is defined by the sum of the length of its straight parts. Comprehension of Piaget's questions by the child would therefore of itself indicate understanding of the additive character of lengths (p. 6).

The problem was clearly recognized, yet the next step--a discussion with subjects of "the additive operation" and then a test of conservation behavior--was not undertaken.

It was earlier suggested that the results obtained here did not demonstrate overwhelming competence on the part of the majority of subjects. Yet the fact remains that instruction of this sort did yield significant performance gains--and this being instruction given

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to a group, for brief periods, and not specifically directed at the test questions. Moreover, some children did achieve very high scores following the training. The original assumption of this experiment appears justified; an explanation of terms does seem to be quite in order. On an individual level, it was probably those children in Piaget's so-called "transition" stage who were best able to utilize the instructional material.

Some of the subjects' own comments are particularly instructive, indicating that children do harbor misconseptions concerning the term "length." On Item 9, for example, one youngster explained her choice on the pretest: "This one is longer because these ends are farther than these ends." On the posttest she answered correctly. One is forced to give thought to Zimiles' point that, for young children who have not been exposed to precise mathematical definitions, perceptual factors are by necessity the determining ones.

Piaget does follow one procedure whose purpose would seem to be to overcome any language barrier. This involves a rephrasing of the question at a level apparently closer to that of his subjects. Thus, instead of asking "Which is longer?" Piaget often repeats, "Which of two ants walking on these lines must make a longer trip?" To the knowledgable experimenter these questions are obviously the same; to the not-so-knowledgable youngster the ant phraseology is probably a clearer presentation of the problem. It is very possible, however, that these two questions are somehow not equivalent to a child.

In this experiment several items (3, 4, 5, 6, 11, 12) were asked in their original form and then in terms of little bugs taking a walk--which one would have to walk more? Unfortunately the several experimenters were not consistent and this information was not obtained for each of these items for every subject. It therefore was not included in the scoring system. Data that are available, however, are worthy of examination; and admittedly intuitive judgments can be made.

A simple, crude tally reveals the fact that in the preponderance of cases the responses to both forms of the question were the same. That is, children were most likely to answer the "length" and the "ant" question either both right or both wrong on a given item. Discrepancies occurred in about 20% of the cases, these about evenly divided in so far as which version was answered correctly. On only one item (#3) did there seem to be a noticeable tendency for the "ant" question to clarify the problem; of those children who did answer differently to the two versions on this task, considerably more were correct when asked about a bug walking than when asked simply about length.

It is difficult to conclude from these data, however, that this was an effective means of tackling the problem of terminology. Rather, it appears that for a number of children the "ant" phraseology is not a more easily understood form of the question but a different question altogether. Such a conclusion is reached from the inconsistency in the responses of individual subjects. On one item a child will say that the bug on the straight path must walk more, on another that the bug on the crooked line has a longer trip. Furthermore, he can answer incorrectly on both the "length" and the "ant" questions for a given item and compound his error by giving two different wrong answers.

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Thus, instead of recognizing the equality of the lines, he may state that the straight line is longer and the ant on the crooked line must walk more. Surely this evidence is indicative of what has already been made clear--the instability of the conservation response. Yet at the same time one can hardly feel satisfied that the second wording was a particularly good way of breaking down a communication barrier.

Finally, the matter of training assumes practical importance because of its educational implications. In the long run, psychological theory is valuable only to the extent that it can be applied to human benefit in everyday situations. Because Piaget concerns himself with how children think, and especially with what mistakes they make, his work has been considered a prime target for schoolroom application. This is certainly a justified and a necessary extension of his writing.

The experiment reported here did take a curricular approach, in that it was conducted in a school, the lessons were given to intact classes, and the instruction was a mathematical explanation of the term "length." The fact that this brief exposure brought both overall gains and some very high scores indicates that even in kindergarten children certainly are ready to begin handling these kinds of problems. The improvement by these subjects might well have been greater with a longer and better program. But there is no doubt that they do use and benefit from direction, a kind of direction not offered by Piaget when he evaluates capability. Furthermore, it was quite clear that a mental set can be induced, as evidenced by the pretested group which was already geared to the discussions that followed.

Conservation per se has never been a topic introduced to young school children. Rather, it is a principle supposedly discovered gradually without special prodding, and one which is necessary for more advanced mathematical behaviors such as measurement. After all, can anyone understand how to apply a ruler if he does not realize that a length does not change when it is moved? The mature adult looking down from his throne of superior wisdom and formal operations knows that of course the answer is no, that you cannot measure without recognizing invariance with movement. But perhaps children are not thinking that way at all. Perhaps they can manipulate rulers and strings quite satisfactorily, while still confused perceptually when a strange experimenter makes strange maneuvers in an artificial situation. In this study the conservation problems were all more difficult than Items #2 and #10, which involved manipulative measurement. It may be that conservation in and of itself is somehow not really relevant to many behaviors for which one would assume it to be a prerequisite.

To the educator it would seem that Piaget has performed an invaluable service in pointing out children's mistakes so that these can be corrected by explanation. It has been seen, however, that a growing debate has ensued as to whether, in fact, such instruction can be of benefit before the child has reached an age at which his thought processes are sufficiently developed. Premature instruction is only in vain, and the youngster will achieve an understanding of the conservation principle on his own anyway. The first part of this hypothesis is undoubtedly true to a certain extent; but the second assumption needs some further examination. Does the child truly learn simply through his own interactions with an information-providing environment, or is this period of revelation the time when adults begin to expect proficiency and so introduce informal instruction, perhaps without even realizing it? Since many of Piaget's age norms seem to reflect standard schooling, the question arises: Does Johnny conserve at age 7 because he has been taught, or is he taught related skills at age 7 because he is now "ready"? Certainly there is no clear-cut answer.

It is somewhat ironic that, in confirming Piaget's basic data, the literature has challenged his whole theoretical framework. Yes, it is true that young children do not succeed on "conservation" problems. But what does this mean in terms of cognitive development and educational practice? Given a variety of language difficulties, a perceptually confusing task, and a definitely artificial situation, we must begin to ask whether conservation need be trained at all. The abundance of literature is testimony to the fact that this issue of conservation is an intriguing one; but in the light of conflicting evidence from all sides, serious problems in experimental procedure, even failure to agree on precisely what behavior is being investigated, perhaps it is time to determine just what relevance this concept does have to supposedly related skills before continuing along the present lines of investigation.

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